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WORLD SUGAR POLICY SIMULATION MODEL: DESCRIPTION AND COMPUTER PROGRAM DOCUMENTATION

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The World Sugar Policy Simulation Model is a dynamic, partial equilibrium, net trade model. It distinguishes 18 countries and regions, and sugar is assumed to be a homogenous commodity. The model is designed for evaluating the effects on the world sugar economy of farm and trade policies by simulating production, consumption, stocks, and trade for sugar over a 10- to 15-year period.

Keywords: International Sugar Trade, Simulation Model

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Abstract

The World Sugar Policy Simulation Model is a dynamic, partial equilibrium, net trade model. It distinguishes 18 countries and regions, and sugar is assumed to be a homogenous commodity. The model is designed for evaluating the effects on the world sugar economy of farm and trade policies by simulating production, consumption, stocks, and trade for sugar over a 10- to 15-year period.

Keywords: International Sugar Trade, Simulation Model

Highlights

The World Sugar Policy Simulation Model is a dynamic, partial equilibrium, net trade model. It is used for evaluating the effects on the world sugar economy of farm and trade policies. This document describes the model structure and computer implementation.

Following are some of the major features of the model:

- There are 18 countries and regions: Algeria, Australia, Brazil, Canada, China, Cuba, Egypt, the European Union, the former Soviet Union, India, Indonesia, Japan, Mexico, South Africa, South Korea, Thailand, the United States, and a "Rest of the World" region.

- Sugar is assumed to be a homogenous commodity. The model does not distinguish between raw sugar and refined sugar. Refined sugar quantities are expressed in raw sugar equivalents.

- The model simulates production, consumption, stocks, and trade for sugar over a 10- to 15-year period.

- It is a dynamic partial equilibrium model. In every year, the model is solved for an equilibrium price such that world sugar supply equals demand.

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INTRODUCTION

Sugarcane is a tall perennial grass that is produced in tropical and subtropical climate zones. It matures in 12 to 16 months and each plant yields several crops, called ratoons. Once the cane is harvested, the sucrose starts breaking down. Thus, to minimize transport costs and sucrose losses, sugarcane mills are located close to the cane fields. They convert the sugarcane into raw sugar that is shipped to refineries for further processing. Refineries remove the film of molasses and impurities that surround the sugar crystals. In contrast to raw sugar producing mills, they are unconstrained by seasonal production patterns and operate throughout the year.

Sugar beets are an annual crop of temperate climate zones. Because of disease problems, sugar beets are always grown in crop rotations. Like cane, sugar beets are bulky and costly to transport. Thus, beet processing facilities tend to be close to the fields. In contrast to sugarcane, however, sugar beets are directly processed into refined sugar. Raw sugar is produced only from sugarcane.

Raw sugar and refined sugar are two distinct products, and both are traded internationally. Beet sugar producing countries only export refined sugar, while cane sugar producing countries can export either raw sugar or refined sugar. In recent years, the share of raw sugar in total sugar exports is about 50 percent (International Sugar Organization, 1994).

The six most important sugar exporters, the European Union, Brazil, Australia, Thailand, Cuba, and the Ukraine, accounted for 73 percent of global exports from 1993/94 to 1995/96 (Table 1). While relatively few countries dominate world sugar exports, demand is less concentrated. The share of the seven most important sugar importing countries and regions, the European Union, Russia, China, the United States, Japan, Korea, and Canada, equaled 46 percent from 1993/94 to 1995/96 (Table 2). The European Union imports sugar because, under the Lome convention, it is required to import sugar under preferential terms from certain African, Caribbean, and Pacific countries. However, these E.U. imports are subject to quotas, and the European Union is a net exporter.

In most years, over 70 percent of world sugar production is consumed domestically, implying that only a small proportion of production is traded internationally. A significant share of this trade takes place under bilateral long-term agreements or on preferential terms such as under the U.S. sugar quota or the European Union's Lome Agreement.

Since only a small proportion of world production is traded freely, small changes in production or government policies tend to have large effects on world sugar markets, and sugar prices are among the most unstable in international trade. Figure 1, which shows Caribbean raw sugar prices and U.S. raw sugar import prices over the last three decades, illustrates this volatility of world sugar prices. Prolonged periods of low prices are briefly interrupted by sharp price peaks.

The Caribbean raw sugar price is usually considered to be the world market price for sugar, while the U.S. import price is the price that U.S. refiners pay for imported raw sugar, i.e., it includes duties. Except in years with high world market prices, there is a significant wedge between the U.S. import price of raw sugar and the world market price. Over the last decade, U.S. import prices fluctuated between US$0.20 and US$0.23, while world market prices were in the range US$0.04 to US$0.13. Thus, when world market prices are low, U.S. sugar producers enjoy considerable protection from sugar imports.

While nominal sugar prices have tended to increase over time, prices adjusted for inflation have decreased. Figure 2 shows the real Caribbean raw sugar prices and the real U.S. raw sugar import prices from 1950 to 1995. Both price series were converted into 1990 values using the U.S. GDP deflator. The figure suggests that, aside from brief periods of extremely high prices, there has been a long-term decline of real sugar prices.

One explanation for the volatility of world sugar prices could be the asymmetric supply response to price changes due to high fixed costs of sugar production. An increase in sugar production in response to rising sugar prices requires significant investments in processing facilities, and it takes some time until new production capacity becomes available. Once these facilities are in place, they tend to be used at full capacity to spread the fixed costs of production. Thus, when prices fall, production remains at high levels. Basically, sugar production is relatively price inelastic in the short run, implying that relatively small changes demand can have significant price effects.

Government policies in many countries aggravate this instability of world market prices by insulating domestic producers and consumers from world market price changes. Since price signals are not transmitted to domestic markets, domestic supply and demand and, thus, sugar stocks and trade do not respond to changing world market conditions. On the contrary, governments may even exacerbate world market price instability by restricting exports in periods of high world market prices and dumping surpluses when prices are low.

In addition to increasing world market instability, sugar policies alter the global distribution of sugar production. By raising domestic prices, industrialized countries stimulate production, thus reducing world market demand or even increasing world market supplies of sugar. The net effect of such policies is that world market prices are lower than they would be in the absence of protective measures and trade flows often reflect domestic sugar policies rather than comparative advantages in sugar production.

Sugar producers, however, are not the only beneficiaries of such protective sugar policies. In the United States, high sugar prices have provided incentives for the development and use of alternative sweeteners. Since corn is the raw material for these sweeteners, corn producers reap some of the benefits of the sugar program.

Four different kinds of corn sweeteners are available: high fructose corn syrup (HFCS), glucose corn syrup, dextrose, and crystalline fructose. Particularly HFCS can substitute for sugar in a range of products and is available at a lower cost. Its consumption did grow rapidly over the last two decades, and HFCS has gained a significant share of the U.S. sweetener market. In 1994, per capita use of HFCS (dry weight) and sugar (refined weight) equaled 56.7 pounds and 65.1 pounds, respectively (USDA).

Development of alternative sweeteners has had a profound impact on the U.S. sugar market. Traditional sugar users were switching to HFCS, thus reducing the domestic demand for

sugar. As a consequence, sugar import quotas had to be tightened to keep domestic sugar prices from falling.

While such policies achieve their goal of protecting U.S. sugar producers, they have negative side effects on sugar exporting countries. Particularly, less developed countries often depend on sugar as a source of revenue and employment. As a group, these countries are the major exporters of sugar. From 1993/94 to 1995/96, 55 percent of world sugar exports came from less developed countries (USDA, PS&D View). Since many of these countries have an apparent comparative advantage for sugarcane production and could export sugar at low cost, sugar policies have serious foreign policy implications and are a source of international disputes.

In industrialized countries, sugar production would be lower and imports higher if protection levels afforded to domestic producers were reduced. However, it is unclear how strong these effects would be and which regions would be affected most. To investigate this and other sugar policy issues, we constructed the World Sugar Policy Simulation Model.

This dynamic simulation model distinguishes 18 countries and regions, including the major sugar exporting and importing countries. Table 3 lists descriptive statistics on production, consumption, trade, and stocks for the countries and regions included in the model. Negative net exports indicate that imports exceed exports. Thus, Australia, Brazil, Cuba, the European Union, South Africa, and Thailand are sugar exporters, while Algeria, Canada, China, Indonesia, Egypt, India, Japan, South Korea, Mexico, the former Soviet Union, the United States, and the Rest of the World region are importers.

The figures show remarkable differences in sugar production, consumption, and trade among countries. Per capita sugar consumption is lowest in China (6.7 kg) and highest in Cuba (73.7 kg). South Korea produces no sugar beets or sugarcane domestically, implying a complete dependence on imports. In contrast, India is a large sugar producer and is almost self-sufficient. However, India's production and trade are variable. In some years, India exports significant amounts of sugar. India also holds significant amounts of carry-over stocks. The stock-to-use ratio is 0.3 in India, while it is only 0.05 in Japan.

MODEL STRUCTURE

Sugar supply and demand for each region are estimated econometrically. However, estimation sometimes was difficult because of data problems, while at other times estimated equations performed poorly in simulations. Therefore, some tuning of the model was necessary, and the final simulation model is a hybrid between an econometric model and a synthetic model. Empirical estimates were used whenever possible, but selected parameters are based on expert advice and personal judgment.

The country submodels include behavioral equations for area harvested, yield, production, domestic consumption, and carry-out stocks. Sugar is assumed to be a homogenous commodity, i.e., no distinction is made between raw sugar and refined sugar. Thus, in the model, all quantities are expressed in raw sugar equivalents. The following sections provide an overview of the conceptual model structure. The appendix summarizes the estimated equations for the various countries.

Sugar Supply

Since sugar is produced using sugarcane or sugar beets, acreage and yield equations for sugar beets and sugarcane are used to model the supply of sugar. Total cane or beet production is the product of area harvested and yield, and sugar production is proportional to the amount of cane and beet produced. However, in some countries, the link between cane production and sugar production is weak since not all cane is used for the production of refined sugar. For instance, in Brazil, substantial amounts of sugarcane are used to produce ethanol. Similarly, India consumes substantial amounts of non-centrifugal sugar. For these countries, explicit sugar production equations are specified.

Area Harvested

Sugar beet area and sugarcane area harvested depend on expected prices of sugar and alternative crops. As a proxy variable for price expectations, lagged prices are included in the acreage equation. In addition to commodity prices, the acreage equations include lagged acreage and a trend variable. In the European Union, the acreage equation also includes a policy parameter, the lagged sugar quota:

$$ah_t^s = f(ah_{t-1}^s,\ p_{t-1}^s,\ p_{t-1}^c,\ g_t,\ t)$$

where ah^s is the sugarcane or sugar beet acreage harvested, p^s is either the world market price of sugar, the domestic sugarcane price, or the domestic sugar beet price, p^c is the price of alternative crops, g is a policy parameter, and t is a time trend.

Yield

Sugar beet and sugarcane yields depend on lagged yields and a time trend:

$$y_t^s = f(y_{t-1}^s,\ t)$$

where y^s is the sugarcane or sugar beet yield, and t is a time trend.

Production

Total sugar production is the sum of cane sugar production and beet sugar production:

$$qp_t^s = ah_t^{sc} * y_t^{sc} * er_t^{sc} + ah_t^{sb} * y_t^{sb} * er_t^{sb}$$

where qp^s is the quantity of sugar produced, er^{sc} is the cane sugar extraction rate, and er^{sb} is the beet sugar extraction rate. The sugar extraction rates are exogenous variables.

In some countries, sugarcane acreage and sugar production are not closely related because a significant proportion of the sugarcane harvested is used for purposes other than centrifugal sugar production. For these countries, sugar production is a function of lagged sugar production, lagged sugar price, and a time trend:

$$qp_t^s = f(qp_{t-1}^s,\ p_{t-1}^s,\ t)$$

where qp^s is the quantity of sugar produced, p^s is the sugar price, and t is a time trend.

Sugar Demand

Sugar demand comprises demand for domestic consumption, carry-out stocks, and net exports. The model specifies behavioral equations for domestic consumption and for carry-out stocks, while net exports are the difference between domestic sugar supply and demand.

Domestic Consumption

Per capita sugar demand is a function of the sugar price, income, and a time trend:

$$cqd_t^s = f(p_t^s,\ cy_t,\ t)$$

where cqd^s is the domestic per capita consumption of sugar, p^s is the price of sugar, cy is per capita income, and t is a time trend.

Total domestic sugar demand is the product of per capita consumption and population.

$$qd_t^s = cqd_t^s * pop_t$$

where qd^s is the total domestic sugar consumption, and pop is the population count.

Carry-out Stocks

Carry-out stocks are a precaution against unexpected supply shortfalls. Thus, these stocks are likely to be related to the level of domestic sugar consumption. However, since the opportunity cost of holding sugar stocks depends on the sugar price, stocks should respond to price changes.

In the model, carry-out stocks are a function of carry-in stocks, domestic consumption, and sugar price.

$$qs_t^s = f(qs_{t-1}^s,\ qd_t^s,\ p_t^s)$$

where qs^s denotes sugar carry-out stocks, and p^s is the sugar price.

Net Exports

Net exports are the difference between domestic sugar supply and demand:

$$qx_t^s = qs_{t-1}^s + qp_t^s - qd_t^s - qs_t^s$$

where qx^s denotes the net exports of sugar. If net exports are negative, the country is a net importer.

Price Linkages

World market prices are converted into domestic prices using the official exchange rate.

$$pm_t^{s,i} = pm_t^{s,us} * er_t^i$$

where $p^{s,i}$ is the domestic price of sugar in country i, and er^i is the exchange rate of country i (domestic currency units per U.S. dollar).

To simulate changes in trade policies, specific and ad valorem tariffs (and subsidies) can be added to the linkage equation for the world price:

$$pm_t^{s,i} = pm_t^{s,us} * er_t^i * (1 + r^{s,i}) + t^{s,i} + t^{s,us}$$

where $r^{s,i}$ is an ad valorem tariff rate, $t^{s,i}$ is a specific tariff quoted in national currency, and $t^{s,us}$ is a specific tariff quoted in U.S. dollars.

If available, domestic sugar beet, sugarcane, and sugar wholesale prices were used to estimate the behavioral equations. The sugar wholesale price is linked to the world market price of sugar in domestic currency.

$$pw_t^{s,i} = f(pm_t^{s,i}, P_t^i)$$

where $pw^{s,i}$ is the wholesale price of sugar, and P_t^i is the GDP deflator of country i.

Sugarcane and sugar beet prices are linked to the sugar wholesale price:

$$pf_t^s = f(pw_t^s)$$

where pf^s is the price of sugarcane or sugar beet.

Prices are converted to real prices using the GDP deflator. For some countries, such as Cuba and the former Soviet Union, nominal U.S. dollar prices are used rather than real prices in domestic currency.

Market Equilibrium

Equilibrium implies that total supply equals total demand, i.e., the sum of net exports of all countries and regions equals zero.

$$\sum_{i=1}^{n} qx_t^{s,i} = 0$$

where $qx^{s,i}$ is the net sugar exports of country i. The model is solved by finding an equilibrium price such that total demand equals total supply.

TARIFF RATE QUOTA

The United States uses tariff rate quotas to limit imports and protect domestic sugar producers. With a tariff rate quota system, the tariff applied to imports depends on the quantity imported. Up to a certain level of imports, a low tariff is applied. Once this quota is filled, imports are taxed at a higher tariff rate. The current U.S. tariff rate quota system uses only two tariff steps: a low tariff and a high tariff. However, in principle, tariff quotas can include more than two tariffs.

Figure 3 shows a tariff rate quota with three tariffs. The horizontal line p_w indicates the world sugar market price. Importers pay a specific tariff t_1 if they import q_1 or less units of sugar; they pay a specific tariff t_2 if they import more than q_1, but less than q_2, units of sugar; and they pay a specific tariff t_3 if they import more than q_2 units of sugar. Therefore, the import price of sugar depends on the world market price and the quantity imported. It equals p_1 if imports are smaller than q_1, p_2 if imports are between q_1 and q_2, and p_3 if imports exceed q_2 units of sugar.

If import demand is given by the downward sloping import demand function D_A, imports equal q_A units of sugar, importers pay a specific tariff t_1, and the import price is p_1. On the other hand, if the import demand schedule is D_C, imports equal q_C units of sugar, importers pay the higher tariff t_2, and the domestic price is p_2.

The situation is more complicated for import demand schedule D_B. This import demand curve intersects the world market supply curve at a discontinuity, as the tariff jumps from t_1 to t_2 at quantity q_1. If the tariff is set at t_1, imports equal q_{B1} units of sugar, and they exceed the quantity q_1. Thus, it seems that imports should be subject to the higher tariff t_2. However, if the tariff t_2 is applied, imports equal only q_{B2} units of sugar, and imports fall short of the quantity q_1. The figure shows that only the tariff rate t^* results in q_1 units of imports. This tariff t^* that results in imports of q_1 units is greater than t_1, but smaller than t_2.

Any of these three import demand scenarios can occur during a simulation. The subroutine that determines U.S. imports first tries tariff t_1. If the imported quantity is smaller than q_1, a valid import solution has been determined, and the simulation continues. If the imported quantity is greater than q_1, the tariff is increased to t_2, and the imported quantity at this tariff level is computed. If it is between q_1 and q_2, a valid import solution has been found, and the simulation continues. If the solution is smaller than q_1, an equation solver is called to find a

tariff t^* such that the quantity imported equals q_1, and the simulation continues. Figure 4 illustrates the tariff rate quota computation.

Finding the tariff t^* that yields a specific amount of imports is straightforward since this tariff is known to be between t_1 and t_2. At the lower bound, t_1, the difference between the imported quantity and the quota, $q_m - q_1$, is positive, while at the upper bound, t_2, this difference is negative. Thus, the solution is bracketed, and simple algorithms, such as Bisection or Brent's method (Press et al.), will always find a solution, t^*, where $q_m - q_1$ equals zero, i.e., the amount of imports, q_m, is equal to the quota, q_1.

If the tariff t_2 is set high enough, a situation like the one depicted by import demand schedule D_C where importers pay the tariff t_2 is unlikely. Therefore, the quantity q_1 will be an upper bound on imports; it acts like a quota. In essence, a tariff rate quota can be used to constrain imports. Setting tariffs prohibitively high above a certain level of imports reduces imports to this level.

MODEL CALIBRATION

All behavioral equations of the model are calibrated to a base period. This ensures that the model replicates base period sugar supply and demand conditions.

To calibrate the behavioral equations, the intercept terms are computed such that base period values are generated for the endogenous variables if the exogenous variables are set to base period values. The procedure is simple and is best demonstrated using an example. Consider the following estimated behavioral equation:

$$y = \hat{\beta}_0 + \hat{\beta}_1 x_1$$

where y is a dependent variable, x is an explanatory variable, and $\hat{\beta}_0$ and $\hat{\beta}_1$ are estimated parameters.

If this equation is estimated with ordinary least squares, the intercept is computed such that the regression line passes through the arithmetic means of x and y:

$$\hat{\beta}_0 = \bar{y} - \hat{\beta}_1 \bar{x}$$

where $\bar{x}$ and $\bar{y}$ indicate the arithmetic means of x and y, respectively.

When calibrating this equation to the base period, the estimated intercept, $\hat{\beta}_0$, is discarded; and a new intercept, $\tilde{\beta}_0$, is computed such that the regression line passes though the base period values of x and y:

$$\tilde{\beta}_0 = y^* - \hat{\beta}_1 x^*$$

where $\tilde{\beta}_0$ denotes the calibrated intercept, and y^* and x^* refer to the base period values of x and y, respectively.

In the calibrated equation,

$$y = \tilde{\beta}_0 + \hat{\beta}_1 x$$

the dependent variable equals y^* whenever the exogenous variable equals x^*. Thus, this "one equation model" replicates the base period.

International sugar supply and demand conditions can change significantly from year to year. Calibrating the model to a base year may cause problems since anomalies in this particular year have a large impact on the model solution. Therefore, the behavioral equations of the world sugar policy simulation model are calibrated using average values for all variables from 1990/91 to 1992/93.

DATA SOURCES

Data for the U.S. sugar economy are supplied by the *U.S. Sugar and Sweetener Situation and Outlook Report* (USDA), the *U.S. Sugar Statistical Compendium* (Angelo et al.), and the *U.S. Corn Sweetener Statistical Compendium* (Gray et al.). Australian sugar data are taken from the *Australian Commodity Statistics* (ABARE). European Union data are provided by *The Agricultural Situation in the Community* (Commission of the European Communities), *Europe: International Agriculture and Trade Reports* (USDA), *Agricultural Statistics of the European Community, 1960-85* (Herlihy et al.). *PS&D View* (USDA) furnished European sugar supply and utilization data. For all other countries, the source of sugar data are *FAOSTAT* (FAO), *PS&D View* (USDA), and *F.O. Licht's World Sugar Statistics* (F.O. Licht).

Macroeconomic and historical population data are supplied by the *International Financial Statistics CD-ROM*. For Cuba and the former Soviet Union, population data are taken from *Population Projections* (USDA). These files also provide projected population growth rates for all countries in the simulation model. Macroeconomic forecasts are provided by the *WEFA Group*.

COMPUTER IMPLEMENTATION

The simulation model is written in Turbo Pascal, version 7.0, and runs on IBM compatible PC's with at least 640k bytes of memory. The main components of the simulation model are an executable file "*sugar.exe*" and a Microsoft Excel file "*su-input.xls*" that contains all input for the simulation program. This file contains tables with simulation parameters, base period values, and exogenous variables. By editing these tables, simulation scenarios are changed.

Figure 5 illustrates the steps involved in running a simulation. To set up a simulation, the user edits the Excel file "*su-input.xls*." This workbook file contains several worksheets. The first worksheet, called "*main*," contains tables with general simulation information such as output file names, base period, and simulation period. Next, there is one worksheet for every country and region in the model. These worksheets are used to enter country and region-specific information.

Following the country and region worksheets, there is one worksheet, called "*wefa*," for the input of macroeconomic forecasts supplied by WEFA.

The last three worksheets, "*output*," "*forms*," and "*module*," are not used for the input of simulation information. The "*output*" worksheet summarizes all input for the simulation program. This worksheet is written to an ASCII file using the "*output*" macro. The "*forms*" worksheet contains formatted tables that, if printed, facilitate the input of data for the base period and lagged variables. The "*module*" worksheet contains the macro "*output*" that generates the input file for the simulation program.

To run a simulation, the user has to fill in the information in the worksheets and execute the macro "*output*" by selecting "*macro*" from the Excel "*tools*" menu. This macro generates the input file "*su-input.prn*" for the simulation program. If a file "*su-input.prn*" exists already, Excel will inquire whether to "*Replace existing ...\su-input.prn?*" The response to this prompt should be "*Yes*." Next, Excel asks whether to "*Save changes in su-input.prn?*" The response to this prompt should be "*No*."

After the macro "*output*" finishes, the simulation is run by typing "*sugar*" at the DOS prompt. The simulation program reads the input file "*su-input.prn*," performs the simulation, and generates two output files in a format that can be edited with a word processor or read into a spreadsheet program for further analysis.

Output Files

The simulation program generates two output files. The file "*1-log.xxx*" contains tables summarizing all input for the simulation. (The *xxx* indicates a file extension that depends on the chosen output file format.) Thus, this file provides a record of all model parameters and exogenous variables for later reference. The file "*1-result.xxx*" contains tables showing the results of the simulation.

Output files can be generated in either of three formats: an ASCII text file (*txt*), a Lotus-123 spreadsheet file (*wk1*), or a Lotus-123 import file (*prn*). ASCII text files (file extension: *txt*) can be loaded into any editor or word processor, or they can be printed with the DOS print or copy commands. However, tables in these files have more than 80 columns, implying that a small font is required to fit tables on regular-sized paper. Lotus-123 spreadsheet files (file extension: *wk1*) can be read by a several programs (including Excel). This format is suitable for further analysis of the simulation results, using spreadsheet programs such as Excel. Lotus-123 import files (file extension: *prn*) are text files in a format that can be imported into spreadsheets. The recommended format for the output file is *wk1*. The file "*1-result.wk1*"contains tables with labels and values generated by the simulation program, but these tables are not formatted for printing. The file "*1-format.xls*" contains formatting information for printing. To generate nicely formatted tables, open the Excel file "*1-format.xls*," and execute the macro "*results*" by selecting macro from the tools menu.

Pascal Files

The Pascal source code for the simulation program is contained in files with "*pas*" file extension. Generally, users of the simulation program do not need to be concerned with these

files. All model input can be changed by modifying the Excel worksheets. The Pascal files are of interest only if the structure of the simulation model has to be changed. For instance, editing the Pascal files and recompiling the program are necessary if equations are added to the model.

For every country or region, there is one "*su-xx.pas*" Pascal file that contains the country model, where *xx* stands for the country code. For example, the file "*su-us.pas*" contains the Pascal source code for the U.S. submodel. In addition to the country files, there are several files with auxiliary procedures. For example, the "*u-solv1.pas*" file contains the equation solver. The main program file is called "*sugar.pas*."

Compiling and linking the source code files produces a set of files with the "*tpu*" file extension and an executable file "*sugar.exe*" that runs the simulation. The "*tpu*" files are compiled Pascal units and are only needed to generate the executable file. These files can be deleted; only the file "*sugar.exe*" is required to run the simulation. After entering "*sugar*" at the prompt, the simulation program reads the input files, runs the simulation, and generates output files with simulation results.

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APPENDIX

MODEL EQUATIONS

(figures in parenthesis are t-values)

Algeria

Sugar beet Area Harvested:

$$ahsb = \underset{(-2.13)}{-6.658} + \underset{(3.07)}{0.517}\ ahsb_1 + \underset{(-0.97)}{-0.149}\ rpmsu_1 + \underset{(2.58)}{0.111}\ t$$

$$n = 22, \quad R^2 = 0.81, \quad \bar{R}^2 = 0.78$$

Sugar beet Yield:

$$ysb = \underset{(0.76)}{8.109} + \underset{(2.05)}{0.365}\ ysb_1 + \underset{(0.38)}{0.055}\ t$$

$$n = 28, \quad R^2 = 0.17, \quad \bar{R}^2 = 0.11$$

Sugar Production:

$$qpsu = qpsb * ysb * ersb$$

Per Capita Sugar Consumption:

$$cqdsu = \underset{(2.97)}{15.582} - \underset{(-1.49)}{0.845}\ rpmsu + \underset{(3.83)}{0.923}\ crgdp$$

$$n = 21, \quad R^2 = 0.64, \quad \bar{R}^2 = 0.60$$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$qssu = \underset{(1.54)}{58.472} + \underset{(2.94)}{0.550}\ qssu_1 - \underset{(-0.27)}{0.010}\ qdsu + \underset{(0.719)}{3.762}\ rpmsu$$

$$n = 22, \quad R^2 = 0.37, \quad \bar{R}^2 = 0.27$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A1: Variable Definitions and Units, Algeria

Name	Definition	Unit
	Endogenous Variables	
ahsb	sugar beet area harvested	1,000 hectares
$ahsb_1$	lagged sugar beet area harvested	1,000 hectares
cqdsu	per capita sugar consumption	kilograms
qdsu	sugar consumption	1,000 metric tons, raw value
qpsu	sugar production	1,000 metric tons, raw value
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar net exports	1,000 metric tons, raw value
rpmsu	real Caribbean sugar price	Dinars/pound, 1990 prices
$rpmsu_1$	lagged real Caribbean sugar price	Dinars/pound, 1990 prices
ysb	sugar beet yield	metric tons/hectare
ysb_1	lagged sugar beet yield	metric tons/hectare
crgdp	per capita real GDP	1,000 Dinars, 1990 prices
	Exogenous Variables	
ersb	sugar beet extraction rate	percent
pop	population	millions
xrate	exchange rate	Dinars/U.S. Dollar

Australia

Sugarcane Area Harvested:

$$ahsc = \underset{(-1.54)}{-88.042} + \underset{(1.93)}{0.451}\ ahsc_1 + \underset{(2.33)}{77.230}\ rpmsu_1 + \underset{(2.70)}{2.910}\ t$$

$$n = 18, \quad R^2 = 0.82, \quad \bar{R}^2 = 0.78$$

Sugarcane Yield:

$$ysc = \underset{(1.40)}{55.906} + \underset{(0.62)}{0.184}\ ysc_1 + \underset{(0.39)}{0.123}\ t$$

$$n = 18, \quad R^2 = 0.03, \quad \bar{R}^2 = -0.10$$

Sugar Production:

$$qpsu = qpsc * ysc * ersc$$

Per Capita Sugar Consumption:

$$cqdsu = \underset{(11.48)}{70.279} - \underset{(-0.77)}{6.273}\ rpwsu - \underset{(-2.30)}{0.793}\ crgdp$$

$$n = 18, \quad R^2 = 0.38, \quad \bar{R}^2 = 0.30$$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$qssu = \underset{(2.30)}{820.737} + \underset{(2.17)}{0.423}\ qssu_1 - \underset{(-1.84)}{0.707}\ qdsu - \underset{(-2.04)}{418.606}\ rpmsu$$

$$n = 19, \quad R^2 = 0.57, \quad \bar{R}^2 = 0.49$$

Sugar Wholesale Price:

$$pwsu = -0.046 + 0.232\ pmsu + 0.425\ gdefl$$
$$(-0.91) \quad (0.70) \qquad (6.79)$$

$$n = 18, \quad R^2 = 0.77, \quad \bar{R}^2 = 0.75$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A2: Variable Definitions and Units, Australia

Name	Definition	Unit
	Endogenous Variables	
ahsc	sugarcane area harvested	1,000 hectares
$ahsc_1$	lagged sugarcane area harvested	1,000 hectares
cqdsu	per capita sugar consumption	kilograms
pmsu	Caribbean sugar price	Aus. Dollars/pound
pwsu	sugar wholesale price	Aus. Dollars/pound
qdsu	sugar consumption	1,000 metric tons, raw value
qpsu	sugar production	1,000 metric tons, raw value
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar net exports	1,000 metric tons, raw value
rpmsu	real Caribbean sugar price	Aus. Dollars/pound, 1990 prices
$rpmsu_1$	lagged real Caribbean sugar price	Aus. Dollars/pound, 1990 prices
rpwsu	real wholesale sugar price	Aus. Dollars/pound, 1990 prices
ysc	sugarcane yield	metric tons/hectare
ysc_1	lagged sugarcane yield	metric tons/hectare
	Exogenous Variables	
crgdp	per capita real GDP	1,000 Aus. Dollars, 1990 prices
ersu	sugarcane extraction rate	percent
gdefl	GDP deflator	1990 = 1
pop	population	millions
xrate	exchange rate	Aus. Dollars/U.S. Dollar

Brazil

Sugar Production:

$$qpsu = \underset{(-6.45)}{-10291} + \underset{(0.901)}{47855716}\ rpmsu_1 + \underset{(11.764)}{222.130}\ t$$

$$n = 31, \quad R^2 = 0.83, \quad R^2 = 0.82$$

Per Capita Sugar Consumption:

$$cqdsu = \underset{(20.606)}{28.733} + \underset{(11.94)}{264.341}\ crgdp$$

$$n = 31, \quad R^2 = 0.83, \quad \bar{R}^2 = 0.83$$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$qssu = \underset{(3.34)}{1563.065} + \underset{(2.56)}{0.411}\ qssu_1 - \underset{(-2.25)}{0.115}\ qdsu - \underset{(-1.70)}{42657631}\ rpmsu$$

$$n = 32, \quad R^2 = 0.46, \quad \bar{R}^2 = 0.40$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A3: Variable Definitions and Units, Brazil

Name	Definition	Unit
	Endogenous Variables	
cqdsu	per capita sugar consumption	kilograms
qdsu	sugar consumption	1,000 metric tons, raw value
qpsu	sugar production	1,000 metric tons, raw value
$qpsu_1$	lagged sugar production	1,000 metric tons, raw value
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar net exports	1,000 metric tons, raw value
rpmsu	real Caribbean sugar price	Reais/pound
$rpmsu_1$	lagged real Caribbean sugar price	Reais/pound
	Exogenous Variables	
crgdp	per capita real GDP	1,000 Reais
pop	population	millions
rgdp	Real GDP	billion Reais
t	trend	-
xrate	exchange rate	Reais/U.S. Dollar

Canada

Sugar beet Area Harvested:

$$ahsb = \underset{(3.34)}{54.491} + \underset{(1.23)}{0.226}\ ahsb_1 + \underset{(1.87)}{11.769}\ rpmsu_1 - \underset{(-1.14)}{0.014}\ rpxwt_1 - \underset{(-2.96)}{0.400}\ t$$

$$n = 30, \quad R^2 = 0.68, \quad \bar{R}^2 = 0.63$$

Sugar beet Yield:

$$ysb = \underset{(0.42)}{2.127} - \underset{(-1.14)}{0.221}\ ysb_1 + \underset{(5.29)}{0.521}\ t$$

$$n = 32, \quad R^2 = 0.62, \quad \bar{R}^2 = 0.60$$

Sugar Production:

$$qpsu = qpsb * ysb * ersb$$

Per Capita Sugar Consumption:

$$cqdsu = \underset{(22.79)}{56.588} - \underset{(-1.02)}{3.736}\ rpmsu - \underset{(-5.08)}{0.608}\ crgdp$$

$$n = 36, \quad R^2 = 0.44, \quad \bar{R}^2 = 0.41$$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$qssu = \underset{(0.15)}{8.521} + \underset{(2.42)}{0.381}\ qssu_1 + \underset{(1.69)}{0.105}\ qdsu - \underset{(-0.01)}{0.26}\ rpmsu$$

$$n = 35, \quad R^2 = 0.37, \quad \bar{R}^2 = 0.31$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A4: Variable Definitions and Units, Canada

Name	Definition	Unit
	Endogenous Variables	
ahsb	sugar beet area harvested	1,000 hectares
$ahsb_1$	lagged sugar beet area harvested	1,000 hectares
cqdsu	per capita sugar consumption	kilograms
pmsu	Caribbean sugar price	Can. dollars/pound
qdsu	sugar consumption	1,000 metric tons, raw value
qpsu	sugar production	1,000 metric tons, raw value
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar net exports	1,000 metric tons, raw value
rpmsu	real Caribbean sugar price	Can. dollars/pound, 1990 prices
rpmsu	real Caribbean sugar price	Can. dollars/pound, 1990 prices
$rpxwt_1$	lagged real wheat export price	Can. dollars/metric ton, 1990 prices
ysb	sugar beet yield	metric tons/hectare
ysb_1	lagged sugar beet yield	metric tons/hectare
	Exogenous Variables	
crgdp	per capita real GDP	1,000 Can. dollars, 1990 prices
ersb	sugar beet extraction rate	percent
pop	population	millions
xrate	exchange rate	Can. dollars/U.S. dollar

China

Sugar beet Area Harvested:

$$ahsb = -2205.927 - 0.541\ ahsb_1 + 3.861\ rpfsb_1 + 29.354\ t$$
$$(-3.42)\quad(-1.79)\quad(2.20)\quad(3.48)$$

$$n = 13, \quad R^2 = 0.73, \quad \bar{R}^2 = 0.64$$

Sugar beet Yield:

$$ysb = -1.506 + 0.839\ ysb_1 + 0.051\ t$$
$$(-0.84)\quad(9.90)\quad(1.78)$$

$$n = 44, \quad R^2 = 80, \quad \bar{R}^2 = 79$$

Sugar beet Farm Price:

$$pfsb = -44.548 + 0.076\ prsu$$
$$(-6.85)\quad(18.23)$$

$$n = 41, \quad R^2 = 0.90, \quad \bar{R}^2 = 0.89$$

Sugarcane Area Harvested:

$$ahsc = -1422.256 + 0.320\ ahsc_1 + 2.194\ rpfsc_1 + 20.900\ t$$
$$(-0.56)\quad(0.74)\quad(0.66)\quad(0.57)$$

$$n = 13, \quad R^2 = 0.87, \quad R^2 = 0.82$$

Sugarcane Yield:

$$ysc = -0.309 + 0.757\ ysc_1 + 0.151\ t$$
$$(-0.08)\quad(7.32)\quad(1.83)$$

$$n = 44, \quad R^2 = 0.80, \quad \bar{R}^2 = 0.79$$

Sugarcane Farm Price:

$$pfsc = -60.809 + 0.073\ prsu$$
$$(-10.48)\quad(19.57)$$

$$n = 41, \quad R^2 = 0.91, \quad \bar{R}^2 = 0.91$$

Sugar Production:

$$qpsu = qpsb * ysb * ersb + qpsc * ysc * ersc$$

Per Capita Sugar Consumption:

$$cqdsu = \underset{(4.14)}{7.925} + \underset{(-2.73)}{-0.001}\ rprsu + \underset{(3.45)}{1.582}\ crgdp$$

$$n = 15, \quad R^2 = 0.85, \quad \bar{R}^2 = 0.83$$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$qssu = \underset{(2.12)}{2170.878} + \underset{(0.59)}{0.162}\ qssu_1 + \underset{(0.18)}{0.027}\ qdsu - \underset{(-2.11)}{2303.706}\ rpmsu$$

$$n = 25, \quad R^2 = 0.39, \quad \bar{R}^2 = 0.30$$

Sugar Retail Price:

$$prsu = \underset{(-0.56)}{-148.033} + \underset{(1.77)}{923.172}\ pmsu + \underset{(4.86)}{2249.992}\ gdefl$$

$$n = 13, \quad R^2 = 0.91, \quad \bar{R}^2 = 0.89$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu + - qdsu - qssu$$

Table A5: Variable Definitions and Units of Measurement, China

Name	Definition	Unit
	Endogenous Variables	
ahsb	sugar beet area harvested	1,000 hectares
$ahsb_1$	lagged sugar beet area harvested	1,000 hectares
ahsc	sugarcane area harvested	1,000 hectares
$ahsc_1$	lagged sugarcane area harvested	1,000 hectares
cqdsu	per capita sugar consumption	kilograms
pfsb	sugar beet farm price	Yuan/metric ton
$pfsb_1$	lagged sugar beet farm price	Yuan/metric ton
pfsc	sugarcane farm price	Yuan/metric ton
$pfsc_1$	lagged sugarcane farm price	Yuan/metric ton
pmsu	Caribbean sugar price	Yuan/pound
prsu	sugar retail price	Yuan/metric ton
qdsu	sugar consumption	1,000 metric tons, raw value
qpsu	sugar production	1,000 metric tons, raw value
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar net exports	1,000 metric tons, raw value
rprsu	real sugar retail price	Yuan/metric ton, 1990 prices
ysb	sugar beet yield	metric tons/hectare
ysb_1	lagged sugar beet yield	metric tons/hectare
ysc	sugarcane yield	metric tons/hectare
ysc_1	lagged sugarcane yield	metric tons/hectare
	Exogenous Variables	
crgdp	per capita real GDP	1,000 Yuan, 1990 prices
ersb	beet sugar extraction rate	percent
ersc	cane sugar extraction rate	percent
gdefl	GDP deflator	1990 = 1
pop	population	millions
xrate	exchange rate	Yuan/U.S. Dollar

Cuba

Sugarcane Area Harvested:

$$ahsc = \underset{(2.16)}{396.714} + \underset{(0.20)}{0.039}\ ahsc_1 - \underset{(-0.34)}{1.065}\ pmsu_1 + \underset{(3.30)}{10.469}\ t - \underset{(-3.09)}{333.300}\ dum_{93}$$

$$n = 34, \quad R^2 = 0.50, \quad R^2 = 0.43$$

Sugarcane Yield:

$$ysc = \underset{(0.90)}{8.677} + \underset{(2.73)}{0.492}\ ysc_1 + \underset{(1.27)}{0.201}\ t + \underset{(-1.70)}{10.743}\ dum_{93}$$

$$n = 34, \quad R^2 = 0.49, \quad \bar{R}^2 = 0.44$$

Sugar Production:

$$qpsu = qpsc * ysc * ersc$$

Per Capita Sugar Consumption:

$$cqdsu = \underset{(-0.08)}{-0.777} + \underset{(-3.59)}{-0.892}\ pmsu + \underset{(6.87)}{0.983}\ t - \underset{(-2.41)}{14.939}\ dum_{93}$$

$$n = 42, \quad R^2 = 0.56, \quad \bar{R}^2 = 0.53$$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$qssu = \underset{(2.75)}{869.435} + \underset{(3.31)}{0.458}\ qssu_1 - \underset{(-2.02)}{0.734}\ qdsu - \underset{(-0.87)}{7.19}\ rpmsu$$

$$n = 41, \quad R^2 = 0.55, \quad \bar{R}^2 = 0.51$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A6: Variable Definitions and Units, Cuba

Name	Definition	Unit
	Endogenous Variables	
ahsc	sugarcane area harvested	1,000 hectares
$ahsc_1$	lagged sugarcane area harvested	1,000 hectares
cqdsu	per capita sugar consumption	kilograms
pmsu	Caribbean sugar price	U.S. Cents/pound
$pmsu_1$	lagged Caribbean sugar price	U.S. Cents/pound
qdsu	sugar consumption	1,000 metric tons, raw value
qpsu	sugar production	1,000 metric tons, raw value
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar net exports	1,000 metric tons, raw value
ysc	sugarcane yield	metric tons/hectare
ysc_1	lagged sugarcane yield	metric tons/hectare
	Exogenous Variables	
ersc	sugarcane extraction rate	percent
pop	population	millions

Egypt

Sugar beet Area Harvested:

$$ahsb = \underset{(-1.42)}{-57.469} - \underset{(-0.55)}{0.234}\ ahsb_1 - \underset{(-1.57)}{34.371}\ rpmsu_1 + \underset{(1.70)}{0.935}\ t$$

$$n = 11, \quad R^2 = 0.51, \quad \bar{R}^2 = 0.30$$

Sugar beet Yield:

$$ysb = \underset{(-2.80)}{-144.783} - \underset{(-0.82)}{0.290}\ ysb_1 + \underset{(3.07)}{2.235}\ t$$

$$n = 11, \quad R^2 = 0.82, \quad \bar{R}^2 = 0.77$$

Sugarcane Area Harvested:

$$ahsc = \underset{(0.36)}{3.808} + \underset{(9.80)}{0.924}\ ahsc_1 + \underset{(0.31)}{0.945}\ rpmsu_1 + \underset{(0.27)}{0.063}\ t$$

$$n = 32, \quad R^2 = 0.98, \quad R^2 = 0.98$$

Sugarcane Yield:

$$ysc = \underset{(0.59)}{6.729} + \underset{(7.28)}{0.850}\ ysc_1 + \underset{(1.20)}{0.090}\ t$$

$$n = 32, \quad R^2 = 0.66, \quad \bar{R}^2 = 0.64$$

Sugar Production:

$$qpsu = qpsb * ysb * ersb + qpsc * ysc * ersc$$

Per Capita Sugar Consumption:

$$cqdsu = \underset{(18.46)}{55.866} - \underset{(-3.00)}{17.513}\ rpmsu - \underset{(-6.84)}{13.036}\ crgdp$$

$$n = 12, \quad R^2 = 0.89, \quad \bar{R}^2 = 0.86$$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$qssu = \underset{(-0.08)}{-1.043} + \underset{(6.94)}{0.786}\ qssu_1 + \underset{(1.41)}{0.015}\ qdsu + \underset{(0.48)}{12.99}\ rpmsu$$

$$n = 40, \quad R^2 = 0.66, \quad \bar{R}^2 = 0.63$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A7: Variable Definitions and Units of Measurement, Egypt

Name	Definition	Unit
	Endogenous Variables	
ahsb	sugar beet area harvested	1,000 hectares
$ahsb_1$	lagged sugar beet area harvested	1,000 hectares
ahsc	sugarcane area harvested	1,000 hectares
$ahsc_1$	lagged sugarcane area harvested	1,000 hectares
cqdsu	per capita sugar consumption	1,000 kilogram
pmsu	Caribbean sugar price	Pounds/pound
qdsu	sugar consumption	1,000 metric tons, raw value
qpsu	sugar production	1,000 metric tons, raw value
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar exports	1,000 metric tons, raw value
rpmsu	Caribbean sugar price	Pounds/pound
$rpmsu_1$	lagged Caribbean sugar price	Pounds/pound
ysb	sugar beet yield	metric tons/hectare
ysb_1	lagged sugar beet yield	metric tons/hectare
ysc	sugarcane yield	metric tons/hectare
ysc_1	lagged sugarcane yield	metric tons/hectare
	Exogenous Variables	
crgdp	per capita real GDP	1000 Pounds
ersb	beet sugar extraction rate	percent
ersc	cane sugar extraction rate	percent
pop	population	millions
xrate	exchange rate	Pounds/US Dollar

European Union

Sugar beet Area Harvested:

$$ahsb = \underset{(2.24)}{434.66} + \underset{(0.72)}{0.136}\ ahsb_1 + \underset{(1.99)}{0.054}\ qqsu_1 + \underset{(2.29)}{355.626}\ rpmsu_1$$

$$+ \underset{(3.39)}{314.235}\ dum_{73} + \underset{(1.09)}{60.968}\ dum_{81} + \underset{(1.42)}{75.579}\ dum_{86}$$

$n = 24, \quad R^2 = 0.92, \quad \bar{R}^2 = 0.89$

Sugar beet Yield:

$$ysb = \underset{(0.47)}{3.184} + \underset{(0.62)}{0.132}\ ysb_1 + \underset{(3.46)}{0.465}\ t$$

$n = 24, \quad R^2 = 0.68, \quad \bar{R}^2 = 0.64$

Sugar Production:

$$qpsu = qpsb * ysb * ersb$$

Per Capita Sugar Consumption:

$$cqdsu = \underset{(12.21)}{48.001} + \underset{(0.21)}{0.033}\ crgdp - \underset{(-1.82)}{0.102}\ t$$

$n = 27, \quad R^2 = 0.14, \quad \bar{R}^2 = 0.07$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$qssu = \underset{(0.65)}{349.885} + \underset{(3.03)}{0.503}\ qssu_1 + \underset{(1.46)}{0.083}\ qdsu - \underset{(-1.24)}{938.29}\ rpmsu$$

$n = 27, \quad R^2 = 0.65, \quad \bar{R}^2 = 0.61$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A9: Variable Definitions and Units, European Union

Name	Definition	Unit
	Endogenous Variables	
ahsb	sugar beet area harvested	1,000 hectares
$ahsb_1$	lagged sugar beet area harvested	1,000 hectares
cqdsu	per capita sugar consumption	kilograms
pmsu	Caribbean sugar price	ECU/pound
qdsu	sugar consumption	1,000 metric tons, raw value
qpsu	sugar production	1,000 metric tons, raw value
$qqsu_1$	lagged sugar quota	1,000 metric tons, white sugar equivalent
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar exports	1,000 metric tons, raw value
rpmsu	Caribbean sugar price	ECU/pound
$rpmsu_1$	lagged Caribbean sugar price	ECU/pound
ysb	sugar beet yield	metric tons/hectare
ysb_1	lagged sugar beet yield	metric tons/hectare
	Exogenous Variables	
crgdp	per capita real GDP	1,000 ECU, 1990 prices
ersb	beet sugar extraction rate	percent
pop	population	millions
t	trend	
xrate	exchange rate	ECU/U.S. Dollar

Former Soviet Union

Sugar beet Area Harvested:

$$ahsb = \underset{(3.41)}{1733.621} + \underset{(6.39)}{0.710}\ ahsb_1 + \underset{(1.51)}{5.829}\ pmsu_1 - \underset{(-2.52)}{9.913}\ t - \underset{(-0.29)}{26.280}\ dum_{87}$$

$$n = 34, \quad R^2 = 0.81, \quad R^2 = 0.78$$

Sugar beet Yield:

$$ysc = \underset{(1.01)}{6.693} + \underset{(3.18)}{0.503}\ ysc_1 + \underset{(0.61)}{0.056}\ t - \underset{(-0.35)}{0.686}\ dum_{87}$$

$$n = 34, \quad R^2 = 0.32, \quad \bar{R}^2 = 0.25$$

Sugar Production:

$$qpwcsu = qpsc * ysc * ersc$$

Per Capita Sugar Consumption:

$$cqdsu = Exogenous$$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$qssu = \underset{(-1.74)}{-494.725} + \underset{(4.39)}{0.547}\ qssu_1 + \underset{(3.30)}{0.149}\ qdsu - \underset{(-1.44)}{16.781}\ pmsu - \underset{(-0.92)}{151.890}\ dum_{87}$$

$$n = 42, \quad R^2 = 0.82, \quad \bar{R}^2 = 0.80$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A8: Variable Definitions and Units, Former Soviet Union

Name	Definition	Unit
	Endogenous Variables	
ahsb	sugar beet area harvested	1,000 hectares
$ahsb_1$	lagged sugar beet area harvested	1,000 hectares
cqdsu	per capita sugar consumption	kilograms
pmsu	Caribbean sugar price	U.S. Cents/pound
$pmsu_1$	lagged Caribbean sugar price	U.S. Cents/pound
qdsu	sugar consumption	1,000 metric tons, raw value
qpsu	sugar production	1,000 metric tons, raw value
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar net exports	1,000 metric tons, raw value
ysb	sugar beet yield	metric tons/hectare
ysb_1	lagged sugar beet yield	metric tons/hectare
	Exogenous Variables	
ersb	beet sugar extraction rate	percent
pop	population	millions
t	trend	
dd	dummy variable	dd = 1 if year > 1986

India

Sugar Production:

$$qpsu = \underset{(-3.11)}{-10566} + \underset{(3.23)}{0.518}\ qpsu_1 + \underset{(0.82)}{117.279}\ rpmsu_1 + \underset{(3.15)}{180.223}\ t$$

$$n = 34, \quad R^2 = 0.90, \quad R^2 = 0.89$$

Per Capita Sugar Consumption:

$$cqdsu = \underset{(-9.36)}{-11.635} - \underset{(-0.37)}{0.30}\ rpmsu + \underset{(4.09)}{1.591}\ crgdp + \underset{(4.95)}{0.186}\ t$$

$$n = 34, \quad R^2 = 0.97, \quad \bar{R}^2 = 0.96$$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$qssu = \underset{(3.41)}{1838.630} + \underset{(1.32)}{0.234}\ qssu_1 + \underset{(1.59)}{0.077}\ qdsu - \underset{(-2.31)}{267.876}\ rpmsu$$

$$n = 34, \quad R^2 = 0.40, \quad \bar{R}^2 = 0.34$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A10: Variable Definitions and Units, India

Name	Definition	Unit
	Endogenous Variables	
cqdsu	per capita sugar consumption	kilograms
pmsu	Caribbean sugar price	U.S. dollars/pound
qdsu	sugar consumption	1,000 metric tons, raw value
qpsu	sugar production	1,000 metric tons, raw value
$qpsu_1$	lagged sugar production	1,000 metric tons, raw value
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar net exports	1,000 metric tons, raw value
rpmsu	real Caribbean sugar price	Rupees/pound, 1990 prices
$rpmsu_1$	lagged real Caribbean sugar price	Rupees/pound, 1990 prices
	Exogenous Variables	
crgdp	per capita real GDP	1,000 Rupees, 1990 prices
pop	population	millions
xrate	exchange rate	Rupees/US Dollar

Indonesia

Sugarcane Area Harvested:

$$ahsc = \underset{(-3.42)}{-401.908} + \underset{(5.35)}{0.615}\ ahsc_1 - \underset{(-1.44)}{0.023}\ rpmsu_1 + \underset{(3.55)}{6.184}\ t$$

$$n = 26, \quad R^2 = 0.99, \quad R^2 = 0.99$$

Sugarcane Yield:

$$ysc = \underset{(3.34)}{177.032} + \underset{(2.72)}{0.438}\ ysc_1 - \underset{(-3.18)}{1.475}\ t$$

$$n = 32, \quad R^2 = 0.82, \quad \bar{R}^2 = 0.81$$

Sugar Production:

$$qpsu = qpsc * ysc * ersc$$

Per Capita Sugar Consumption:

$$cqdsu = \underset{(4.27)}{4.469} + \underset{(-0.205)}{-0.0003}\ rpmsu + \underset{(8.34)}{0.009}\ crgdp$$

$$n = 28, \quad R^2 = 0.77, \quad \bar{R}^2 = 0.75$$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$qssu = \underset{(4.19)}{517.846} + \underset{(0.14)}{0.030}\ qssu_1 - \underset{(-0.67)}{0.027}\ qdsu - \underset{(-1.36)}{0.178}\ rpmsu$$

$$n = 28, \quad R^2 = 0.07, \quad \bar{R}^2 = -0.04$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A11: Variable Definitions and Units, Indonesia

Name	Definition	Unit
	Endogenous Variables	
ahsc	sugarcane area harvested	1,000 hectares
$ahsc_1$	lagged sugarcane area harvested	1,000 hectares
cqdsu	per capita sugar consumption	kilograms
qdsu	sugar consumption	1,000 metric tons, raw value
qpsu	sugar production	1,000 metric tons, raw value
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar net exports	1,000 metric tons, raw value
rpmsu	real Caribbean sugar price	Rupiah/pound, 1990 prices
ysc	sugarcane yield	metric tons/hectare
ysc_1	lagged sugarcane yield	metric tons/hectare
	Exogenous Variables	
crgdp	per capita real GDP	1,000 Rupiah, 1990 prices
ersc	sugarcane extraction rate	percent
pop	population	Millions
t	trend	
xrate	exchange rate	Rupiah/US Dollar

Japan

Sugar beet Area Harvested:

$$ahsb = -9.477 + 0.836\ ahsb_1 + 0.001\ rpfsb_1$$
$$(-1.06) \quad (9.37) \quad (2.66)$$

$$n = 23, \quad R^2 = 0.84, \quad \bar{R}^2 = 0.82$$

Sugar beet Yield:

$$ysb = -10.484 + 0.467\ ysb_1 + 0.447\ t$$
$$(-1.04) \quad (2.66) \quad (2.17)$$

$$n = 32, \quad R^2 = 0.75, \quad \bar{R}^2 = 0.74$$

Sugar beet Farm Price:

$$pfsb = -718.465 + 1.073\ pisb + 7.864\ pmsu$$
$$(-1.48) \quad (43.21) \quad (1.36)$$

$$n = 23, \quad R^2 = 0.99, \quad \bar{R}^2 = 0.99$$

Sugarcane Area Harvested:

$$ahsc = 1.882 + 0.761\ ahsc_1 + 0.0003\ rpfsc_1$$
$$(0.28) \quad (2.78) \quad (1.25)$$

$$n = 18, \quad R^2 = 0.67, \quad R^2 = 0.62$$

Sugarcane Yield:

$$ysc = 67.473 - 0.081\ ysc_1 + 0.047\ t$$
$$(4.44) \quad (-0.44) \quad (0.38)$$

$$n = 32, \quad R^2 = 0.01, \quad \bar{R}^2 = -0.06$$

Sugarcane Farm Price:

$$pfsc = -643.802 + 1.061\ pisc + 3.113\ pmsu$$
$$(-0.61) \quad (21.31) \quad (0.32)$$

$$n = 18, \quad R^2 = 0.97, \quad \bar{R}^2 = 0.97$$

Sugar Production:

$$qpsu = qpsb * ysb * ersb + qpsc * ysc * ersc$$

Per Capita Sugar Consumption:

$$\underset{(6.31)}{cqdsu = 84.842} \underset{(-1.89)}{- 0.041\ rpwsu} + \underset{(1.35)}{0.004\ crgdp} \underset{(-3.22)}{- 0.819\ t}$$

$$n = 23, \quad R^2 = 0.80, \quad \bar{R}^2 = 0.77$$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$\underset{(1.09)}{qssu = 197.083} + \underset{(2.95)}{0.499\ qssu_1} \underset{(-0.50)}{- 0.034\ qdsu} + \underset{(1.71)}{1.241\ rpmsu}$$

$$n = 31, \quad R^2 = 0.32, \quad \bar{R}^2 = 0.24$$

Sugar Wholesale Price:

$$\underset{(2.28)}{pwsu = 27.038} + \underset{(4.91)}{0.003\ pisb} + \underset{(2.19)}{0.311\ pmsu}$$

$$n = 23, \quad R^2 = 0.55, \quad \bar{R}^2 = 0.50$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A12: Variable Definitions and Units of Measurement, Japan

Name	Definition	Unit
	Endogenous Variables	
ahsb	sugar beet area harvested	1,000 hectares
$ahsb_1$	lagged sugar beet area harvested	1,000 hectares
ahsc	sugarcane area harvested	1,000 hectares
$ahsc_1$	lagged sugarcane area harvested	1,000 hectares
cqdsu	per capita sugar consumption	kilograms
pfsb	sugar beet farm price	Yen/metric ton
$pfsb_1$	lagged sugar beet farm price	Yen/metric ton
pfsc	sugarcane farm price	Yen/metric ton
$pfsc_1$	lagged sugarcane farm price	Yen/metric ton
pmsu	Caribbean sugar Price	Yen/pound
pwsu	sugar wholesale price	Yen/pound
$pwsu_1$	lagged sugar wholesale price	Yen/pound
qdsu	sugar consumption	1,000 metric tons, raw value
qmsu	sugar imports	1,000 metric tons, raw value
qpsu	sugar production	1,000 metric tons, raw value
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar exports	1,000 metric tons, raw value
ysb	sugar beet yield	metric tons
ysb_1	lagged sugar beet yield	metric tons
ysc	sugarcane yield	metric tons
ysc_1	lagged sugarcane yield	metric tons
	Exogenous Variables	
crgnp	per capita real GNP	1,000 Yen
ersb	beet sugar extraction rate	percent
ersc	cane sugar extraction rate	percent
gdefl	GNP deflator	1990 = 1
pisb	sugar beet support price	Yen/metric ton
pisc	sugarcane support price	Yen/metric ton
pop	population	millions
xrate	exchange rate	Yen/US Dollar

Mexico

Sugarcane Area Harvested:

$$ahsc = \underset{(2.67)}{118.954} + \underset{(4.56)}{0.608}\ ahsc_1 - \underset{(-0.31)}{4.293}\ rpmsu_1 + \underset{(1.36)}{1.116}\ t$$

$$n = 32, \quad R^2 = 0.77, \quad R^2 = 0.75$$

Sugarcane Yield:

$$ysc = \underset{(3.41)}{31.483} + \underset{(1.42)}{0.260}\ ysc_1 + \underset{(2.73)}{0.233}\ t$$

$$n = 32, \quad R^2 = 0.47, \quad \bar{R}^2 = 0.43$$

Sugar Production:

$$qpsu = qpsc * ysc * ersc$$

Per Capita Sugar Consumption:

$$cqdsu = \underset{(11.45)}{17.588} - \underset{(-0.50)}{0.418}\ rpmsu + \underset{(17.55)}{3.607}\ crgdp$$

$$n = 33, \quad R^2 = 0.91, \quad \bar{R}^2 = 0.90$$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$qssu = \underset{(0.86)}{152.306} + \underset{(3.42)}{0.553}\ qssu_1 + \underset{(1.29)}{0.081}\ qdsu - \underset{(-0.68)}{106.481}\ rpmsu$$

$$n = 34, \quad R^2 = 0.55, \quad \bar{R}^2 = 0.50$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A13: Variable Definitions and Units, Mexico

Name	Definition	Unit
	Endogenous Variables	
ahsc	sugarcane area harvested	1,000 hectares
$ahsc_1$	lagged sugarcane area harvested	1,000 hectares
cqdsu	per capita sugar consumption	kilograms
qdsu	sugar consumption	1,000 metric tons, raw value
qpsu	sugar production	1,000 metric tons, raw value
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar net exports	1,000 metric tons, raw value
rpmsu	real Caribbean sugar price	Pesos/pound
ysc	sugarcane yield	metric tons/hectare
ysc_1	lagged sugarcane yield	metric tons/hectare
	Exogenous Variables	
crgdp	per capita real GDP	1,000 Pesos, 1990 prices
ersc	cane sugar extraction rate	percent
pop	population	millions
t	trend	
xrate	exchange rate	Pesos/U.S. Dollar

South Africa

Sugarcane Area Harvested:

$$ahsc = \underset{(-1.49)}{-71.296} + \underset{(2.76)}{0.591}\ ahsc_1 + \underset{(0.50)}{5.005}\ rpmsu_1 + \underset{(1.90)}{2.039}\ t$$

$$n = 25, \quad R^2 = 0.89, \quad \bar{R}^2 = 0.88$$

Sugarcane Yield:

$$ysc = \underset{(3.66)}{157.549} + \underset{(1.05)}{0.209}\ ysc_1 - \underset{(-3.20)}{1.199}\ t$$

$$n = 25, \quad R^2 = 0.61, \quad \bar{R}^2 = 0.57$$

Sugar Production:

$$qpsu = qpsc * ysc * ersc$$

Per Capita Sugar Consumption:

$$cqdsu = \underset{(-0.43)}{-6.921} + \underset{(4.88)}{6.77}\ crgdp + \underset{(-0.59)}{-0.051}\ t$$

$$n = 25, \quad R^2 = 0.65, \quad \bar{R}^2 = 0.62$$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$qssu = \underset{(-0.45)}{-69.752} + \underset{(0.17)}{0.034}\ qssu_1 + \underset{(2.23)}{0.285}\ qdsu - \underset{(-1.73)}{101.09}\ rpmsu$$

$$n = 25, \quad R^2 = 0.42, \quad \bar{R}^2 = 0.34$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A14: Variable Definitions and Units, South Africa

Name	Definition	Unit
	Endogenous Variables	
ahsc	sugarcane Area harvested	1,000 hectares
$ahsc_1$	lagged sugarcane area harvested	1,000 hectares
cqdsu	per capita sugar consumption	kilograms
$pmsu_1$	lagged Caribbean sugar price	Rand/pound
qdsu	sugar consumption	1,000 metric tons, raw value
qpsu	sugar production	1,000 metric tons, raw value
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar net exports	1,000 metric tons, raw value
rpmsu	real Caribbean sugar price	Rand/pound
ysc	sugarcane yield	metric tons/hectare
ysc_1	lagged sugarcane yield	metric tons/hectare
	Exogenous Variables	
crgdp	per capita real GDP	1,000 Rand, 1990 prices
ersc	cane sugar extraction rate	percent
pop	population	Millions
t	trend	
xrate	exchange rate	Rand/U.S. Dollar

South Korea

Per Capita Sugar Consumption:

$$cqdsu = -0.471 - 0.004\ rpwsu + 0.004\ crgdp + 0.087$$
$$(-0.03)\quad (-1.62)\qquad (3.13)\qquad (0.37)$$

$$n = 17, \quad R^2 = 0.96, \quad \bar{R}^2 = 0.95$$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$qssu = 35.953 + 0.711\ qssu_1 + 0.008\ qdsu - 0.077\ rpmsu$$
$$(1.10)\quad (4.19)\qquad (0.15)\qquad (-1.30)$$

$$n = 22, \quad R^2 = 0.74, \quad \bar{R}^2 = 0.70$$

Sugar Wholesale Price:

$$pwsu = 63.206 + 1.307\ pmsu + 164.329\ gdefl$$
$$(1.66)\quad (2.34)\qquad (3.40)$$

$$n = 20, \quad R^2 = 0.60, \quad \bar{R}^2 = 0.55$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A15: Variable Definitions and Units of Measurement, South Korea

Name	Definition	Unit
	Endogenous Variables	
cqdsu	per capita sugar consumption	kilograms
pmsu	Caribbean sugar Price	Won/pound
pwsu	sugar wholesale price	Won/pound
$pwsu_1$	lagged sugar wholesale price	Won/pound
qdsu	sugar consumption	1,000 metric tons, raw value
qmsu	sugar imports	1,000 metric tons, raw value
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar exports	1,000 metric tons, raw value
rpwsu	real sugar Wholesale Price	Won/pound, 1990 prices
	Exogenous Variables	
crgdp	per capita real GDP	1,000 Won, 1990 prices
pop	population	millions
xrate	exchange rate	Won/U.S. Dollar

Thailand

Sugarcane Area Harvested:

$$ahsc = \underset{(-2.36)}{-537.683} + \underset{(5.96)}{0.754}\ ahsc_1 + \underset{(1.49)}{5.313}\ rpmsu_1 + \underset{(2.34)}{8.184}\ t$$

$$n = 32, \quad R^2 = 0.96, \quad R^2 = 0.96$$

Sugarcane Yield:

$$ysc = \underset{(1.84)}{18.883} + \underset{(1.66)}{0.304}\ ysc_1 + \underset{(1.02)}{0.144}\ t$$

$$n = 32, \quad R^2 = 0.19, \quad \bar{R}^2 = 0.13$$

Sugar Production:

$$qpsu = qpsc * ysc * ersc$$

Per Capita Sugar Consumption:

$$cqdsu = \underset{(6.42)}{8.234} + \underset{(-2.18)}{-0.419}\ rpwsu + \underset{(17.28)}{0.357}\ crgdp$$

$$n = 23, \quad R^2 = 0.94, \quad \bar{R}^2 = 0.94$$

Sugar Consumption:

$$qdsu = cqdsu * pop$$

Sugar Carry-out Stocks:

$$qssu = \underset{(-1.03)}{-37.958} + \underset{(3.27)}{0.510}\ qssu_1 + \underset{(3.38)}{0.185}\ qdsu + \underset{(1.02)}{6.273}\ rpmsu$$

$$n = 41, \quad R^2 = 0.65, \quad \bar{R}^2 = 0.63$$

Sugar Wholesale Price:

$$pwsu = \underset{(0.13)}{0.056} + \underset{(0.93)}{0.095}\ pmsu + \underset{(9.44)}{5.190}\ gdefl$$

$$n = 23, \quad R^2 = 0.83, \quad \bar{R}^2 = 0.81$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A16: Variable Definitions and Units, Thailand

Name	Definition	Unit
	Endogenous Variables	
ahsc	sugarcane area harvested	1,000 hectares
$ahsc_1$	lagged sugarcane area harvested	1,000 hectares
cqdsu	per capita sugar consumption	kilograms
pmsu	Caribbean sugar price	Baht/pound
pwsu	sugar wholesale price	Baht/pound
qdsu	sugar consumption	1,000 metric tons, raw value
qpsu	sugar production	1,000 metric tons, raw value
qssu	sugar carry-out stocks	1,000 metric tons, raw value
$qssu_1$	sugar carry-in stocks	1,000 metric tons, raw value
qxsu	sugar exports	1,000 metric tons, raw value
rpwsu	real sugar wholesale price	Baht/pound, 1990 prices
ysc	sugarcane yield	metric tons/hectare
ysc_1	lagged sugarcane yield	metric tons/hectare
	Exogenous Variables	
crgdp	real per capita GDP	1,000 Baht, 1990 prices
ersc	cane sugar extraction rate	percent
pop	population	millions
xrate	exchange rate	Baht/U.S. Dollar

United States

Sugar beet Area Harvested:

$$ahsb = \underset{(2.33)}{385.99} + \underset{(5.12)}{0.594}\ ahsb_1 + \underset{(3.51)}{6.265}\ rpfsb_1 - \underset{(-2.59)}{36.961}\ rpfwt_1$$

$$n = 35, \quad R^2 = 0.58, \quad \bar{R}^2 = 0.54$$

Sugar beet Yield:

$$ysb = \underset{(4.46)}{7.47} + \underset{(1.93)}{0.286}\ ysb_1 + \underset{(6.69)}{0.0827}\ t$$

$$n = 45, \quad R^2 = 0.70, \quad \bar{R}^2 = 0.68$$

Sugar beet Farm Price:

$$pfsb = \underset{(4.40)}{3.679} + \underset{(32.23)}{1.428}\ pmsu$$

$$n = 35, \quad R^2 = 0.97, \quad \bar{R}^2 = 0.97$$

Sugarcane Area Harvested:

$$ahsc = \underset{(2.03)}{155.498} + \underset{(10.63)}{0.830}\ ahsc_1 + \underset{(1.01)}{0.474}\ rpfsc_1 - \underset{(-1.39)}{0.495}\ rpfct_1$$

$$n = 35, \quad R^2 = 0.87, \quad R^2 = 0.86$$

Sugarcane Yield:

$$ysc = \underset{(4.02)}{23.557} + \underset{(4.81)}{0.553}\ ysc_1 - \underset{(-3.09)}{0.088}\ t$$

$$n = 45, \quad R^2 = 0.63, \quad \bar{R}^2 = 0.62$$

Sugarcane Farm Price:

$$pfsc = \underset{(-0.41)}{-0.294} + \underset{(32.77)}{1.248}\ pmsu$$

$$n = 35, \quad R^2 = 0.97, \quad \bar{R}^2 = 0.97$$

Sugar Production:

$$qpsu = qpsb * ysb * ersb + qpsc * ysc * ersc$$

Per Capita Sugar Consumption:

$$\underset{(5.09)}{cqdsu = 220.242} + \underset{(-2.02)}{-1.191\ rpmsu} + \underset{(2.14)}{1.552\ rpwcs} + \underset{(1.30)}{4.327\ crgdp} - \underset{(-2.60)}{2.740\ t}$$

$$n = 20, \quad R^2 = 0.77, \quad \bar{R}^2 = 0.71$$

Sugar Consumption:

$$qdsu = 0.5 * cqdsu * pop$$

Sugar Carry-out Stocks:

$$\underset{(0.84)}{qssu = 424.685} + \underset{(2.86)}{0.513\ qssu_1} + \underset{(1.10)}{0.052\ qdsu} - \underset{(-1.23)}{5.336\ rpmsu}$$

$$n = 25, \quad R^2 = 0.39, \quad \bar{R}^2 = 0.30$$

Sugar Wholesale Price:

$$\underset{(2.73)}{pwsu = 1.631} + \underset{(32.95)}{1.045\ pmsu}$$

$$n = 35, \quad R^2 = 0.97, \quad \bar{R}^2 = 0.97$$

Sugar Net Exports:

$$qxsu = qssu_1 + qpsu - qdsu - qssu$$

Table A17: Variable Definitions and Units of Measurement, United States

Variable	Definition	Unit
	Endogenous Variables	
ahsb	sugar beet area harvested	1,000 acres
$ahsb_1$	lagged sugar beet area harvested	1,000 acres
ahsc	sugarcane area harvested	1,000 acres
$ahsc_1$	lagged sugarcane acreage	1,000 acres
cqdsu	per capita sugar consumption	pounds
pfsb	sugar beet farm price	dollars/short ton
pfsc	sugarcane farm price	dollars/short ton
pmsu	raw sugar import price, duty paid	cents/pound, raw
qdsu	sugar consumption	1,000 metric tons, raw value
qmsu	sugar imports	1,000 metric tons, raw value
qpwbsu	beet sugar production	1,000 short tons, raw value
qpwcsu	cane sugar production	1,000 short tons, raw value
qssu	sugar carry-out stocks	1,000 short ton, raw value
$qssu_1$	sugar carry-in stocks	1,000 short ton, raw value
$rpfsb_1$	lagged real sugar beet farm price	dollars/short ton, 1990 prices
$rpfsc_1$	lagged real sugarcane farm price	dollars/short ton, 1990 prices
rpmsu	real raw sugar import price, duty paid	cents/pound raw
ysb	sugar beet yield	short tons/acre
ysb_1	lagged sugar beet yield	short tons/acre
ysc	sugarcane yield	short tons/acre
ysc_1	lagged sugarcane yield	short tons/acre
crgdp	real per capita GDP	1000 dollars, 1990 prices
	Exogenous Variables	
ersb	beet sugar extraction rate	percent
ersc	cane sugar extraction rate	percent
pop	population	millions
$rpfct_1$	lagged real cotton farm price	cents/pound, 1990 prices
$rpfwt_1$	lagged real wheat farm price	dollars/bushel, 1990 prices
rpwhfcs	real HFCS-42 price	cents/lb, dry weight, 1990 prices
t	trend	

Rest of the World

Sugar Net Exports:

$$qxsu = \alpha_0 + \alpha_1 \, pmsu + \alpha_2 \, pmsu_1 + \alpha_3 \, t$$

Table A18: Variable Definitions and Units, Rest of the World

Name	Definition	Unit
	Endogenous Variables	
qxsu	sugar net exports	1,000 metric tons, raw value
pmsu	Caribbean sugar price	U.S. cents/pound
$pmsu_1$	lagged Caribbean sugar price	U.S. cents/pound
	Exogenous Variables	
t	trend	

Table 1: World Sugar Trade by leading Sugar Exporters

Sugar Exporters	1990/91 - 1992/93	1993/94 - 1995/96
	- - - - - - - - million metric tons, raw value - - - - - - - -	
European Union (15)	6.88	6.38
Brazil	1.77	3.95
Australia	2.88	3.92
Thailand	3.04	3.77
Cuba	5.56	3.05
Ukraine	2.32	1.89
Total leading exporters	22.45	22.96
World Total Exports	32.21	31.56

Source: U.S. Department of Agriculture. *PS&D View*.

Table 2: World Sugar Trade by Leading Sugar Importers

Sugar Importers	1990/91 - 1992/93	1993/94 - 1995/96
	- - - - - - - - million metric tons, raw value - - - - - - - -	
European Union (15)	3.45	3.08
Russia	3.64	2.95
China	1.05	2.31
United States	2.17	1.78
Japan	1.78	1.69
Korea	1.24	1.31
Canada	1.06	1.13
Total Leading Importers	14.39	14.25
World Total Imports	30.44	30.99

Source: U.S. Department of Agriculture. *PS&D View*.

Table 3: World Sugar Supply and Utilization, 1990/91 to 1995/96 Average

Country	Crop*	Production	Consumption	Net Exports	Ending Stocks	Per Capita Consumption	Stocks/Use Ratio
		- - - - - - - - - - 1000 metric tons, raw value - - - - - - - - - -				kilograms	percent
Algeria	B	10	895	-885	110	33.20	12.3
Australia	C	4,273	890	3,394	185	50.30	20.7
Brazil	C	10,372	7,598	2,824	773	48.86	10.2
Canada	B	141	1,198	-1,061	178	43.47	14.8
China	B/C	7,205	7,825	-932	1,669	6.68	21.3
Cuba	C	5,038	793	4,308	222	73.72	28.0
Egypt	B/C	1,028	1,546	-527	187	26.08	12.1
European Union (12)	B	16,422	12,993	3,407	2,452	37.32	18.9
Former Soviet Union	B	7,034	10,794	-3,661	2,109	36.77	19.5
India	C	14,095	13,711	-9	4,157	15.33	30.3
Indonesia	C	2,300	2,630	-288	377	13.44	14.3
Japan	B/C	888	2,628	-1,736	131	21.11	5.0
Mexico	C	4,053	4,302	-210	869	48.04	20.2
South Africa	C	1,830	1,389	435	314	32.86	22.6
South Korea	-	0	998	-1,004	112	22.49	11.2
Thailand	C	4,857	1,405	3,403	436	24.11	31.0
United States	B/C	6,833	8,345	-1,507	1,278	32.49	15.3
Rest of the World	B/C	28,689	33,443	-4,735	5,769	19.69	17.3
World Total		115,067	113,383	1,217	21,325	20.56	18.8

*B = Sugar beet, C = Sugarcane.

Source: U.S. Department of Agriculture. PS&D View.
U.S. Department of Agriculture. Population Projections.

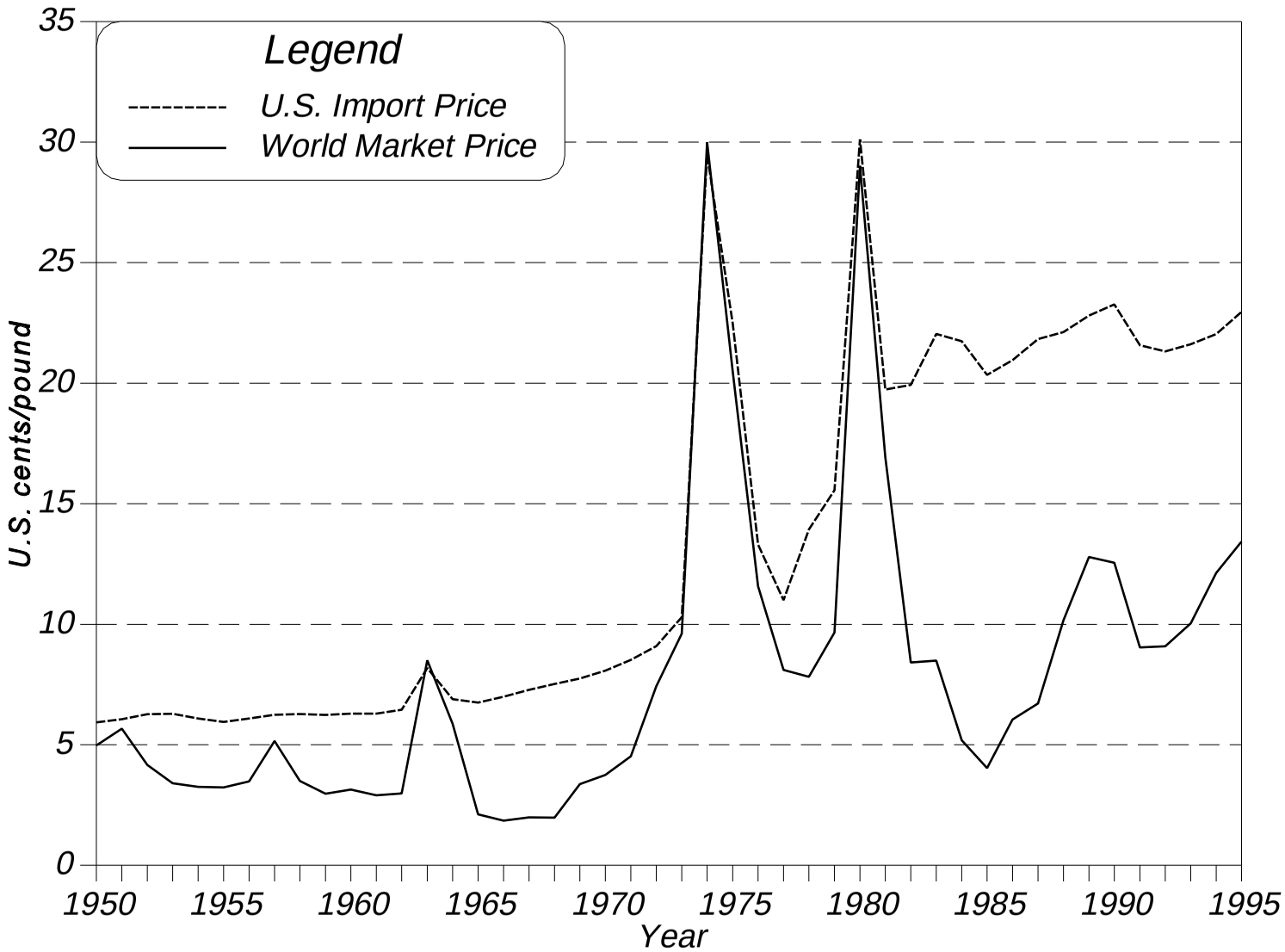

Figure 1: Raw Sugar Prices, 1950-95

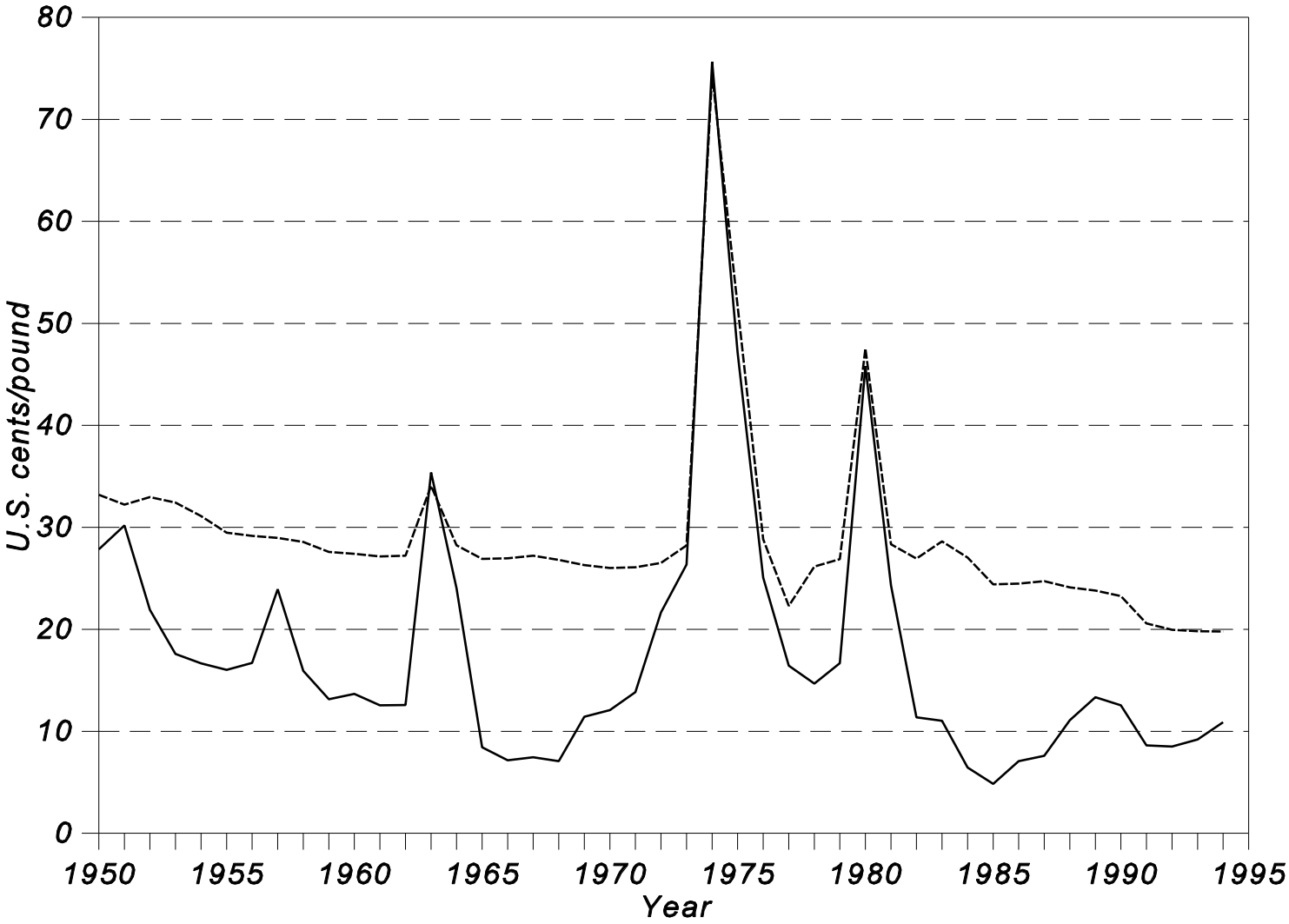

Figure 2: Real Raw Sugar Prices, 1950-95

Deflated with the U.S. GDP Deflator (1990=1)

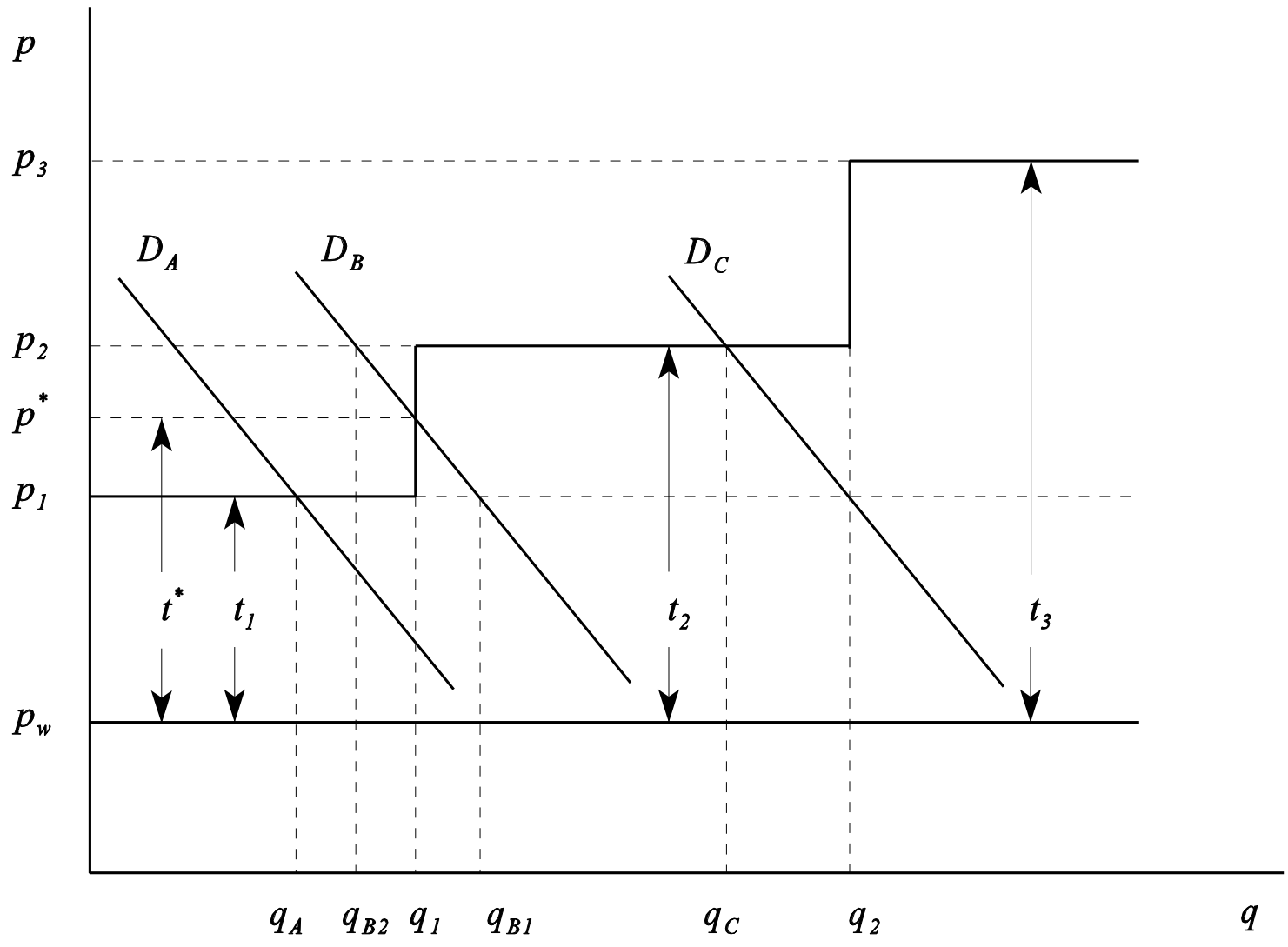

Figure 3: Tariff Rate Quota