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Impacts of the Brazilian Ethanol Program on the World Ethanol and Sugar Market : An Econometric Simulation Approach

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The sugar market in Brazil is closely related to the ethanol market. Although the Brazilian government has abolished all sugar market intervention measures, it still retains control over the ethanol-gasoline blend ratio. In this study, we investigate the implications of a change in this blend ratio on the world ethanol and sugar markets—particularly in terms of production, consumption, exports and imports—by applying a newly developed World Ethanol-Sugar Market Model. Our simulation suggests moderate impacts on world ethanol and sugar markets.

Key words : Brazil, ethanol, sugarcane, sugar.

1. Introduction

The global sugar market operates under varying degrees of government intervention. In many countries, production, trade and even consumption levels of sugar are subject to government controls. Government policies that influence the sugar market have been strengthening and becoming more common since the mid-1970s. Today, the world sugar market is affected by government programs that fall into three broad categories : agricultural, energy and environmental policies. Air pollution and ground water pollution issues in the U. S. are examples of links between environmental and energy policies, while energy policy decisions in Brazil and India are examples of links between agricultural and energy programs.

The world sugar and ethanol markets have a strong influence on each other because most sugarcane is directed towards ethanol production nowadays. Among the major sugar-producing countries, Brazil is the world's largest producer of sugarcane and sugarcane-based ethanol. In 1999, less than half of the sugarcane produced in Brazil (estimated as ranging from 35.0 to 47.2%)[1] went toward sugar production, and the remainder to the ethanol market. Therefore, developments in Brazil have considerable implications for the world sugar and ethanol markets.

During the past three decades, the government of Brazil has implemented powerful intervention programs for its sugar market through its ethanol program. However, the role of the government changed in the late 1990s. Following the deregulation of its ethanol program during the 1998-99 period, the government no longer exercises direct control over sugar production and exports. At present, the government can only exert influence by setting the ethanol-to-fuel blend ratio. In recent years, the Ministry of Agriculture of Brazil has set the anhydrous ethanol blend to gasoline in the 20-25% range (with a permitted variation of ±1%) as a means of balancing the relationship between supply and demand for sugar and ethanol. The ratio became 25% in July 2003, close to the legal maximum of 26%. In the near future, the most likely decision will involve

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planned compulsory usage of ethanol-blend diesel fuel.

Several studies have noted the relationship between the sugar and ethanol markets in Brazil. Bolling and Suarez [2] mentioned that the main determinant of sugar production is ethanol policy. Walter [12] stressed the links between the ethanol and sugar markets in Brazil, and Schmitz, Seale and Buzzanell [10] investigated how an increase in the ethanol blend ratio affects the consumption and production of sugarcane, both in Brazil and globally (but without utilizing world sugar and ethanol models). However, none of these studies analyzed how the imposition of ethanol-blend diesel fuel in Brazil would affect world sugar and ethanol markets.

Several studies have attempted to derive projections for the world sugar and U.S. ethanol markets. Koo and Taylor [7], for example, projected the main 17 sugar-producing and-consuming countries' markets to the year 2012. DiPardo [3] projected U.S. ethanol production to the year 2020. However, neither of these studies incorporated the relationship between the sugar and ethanol markets.

Our study is the first to evaluate the impact that compulsory ethanol-blend diesel fuel usage in Brazil would have on world sugar and ethanol markets, using a World Ethanol-Sugar Market model. In this study, the link between the agricultural (sugarcane and sugar) and energy (ethanol) markets is analyzed and translated into econometrically estimated structural equations based on the model. In the next section, a brief overview of the Brazilian ethanol program is presented, followed by an explanation of the World Ethanol-Sugar Market Model that we applied in evaluating it. Baseline projection figures are discussed in the third section, and the market impacts in the fourth section. The last section summarizes our conclusion.

2. The World Ethanol-Sugar Market Model

1) Overview of the world ethanol-sugar markets model

A World Ethanol-Sugar Market Model was developed in order to analyze how ethanol, energy or environmental policies in major sugar-producing countries affect not only the domestic and world ethanol markets but also corresponding sugar markets. The model is developed as a dynamic partial equilibrium model that extends to the world sugar and ethanol markets. The world sugar market consists of 23 major sugar-producing countries : Brazil, U.S., EU15, Australia, Mexico, Japan, Korean Republic, Canada, Hungary, Poland, Switzerland, Turkey, New Zealand, Norway, Czech Republic, Slovakia, India, China Mainland, Cuba, ACP countries, South Africa, Thailand and Former USSR. The world ethanol market consists of 20 major country markets : Brazil, U.S., EU15, Mexico, Japan, Korean Republic, Canada, Hungary, Poland, Switzerland, Turkey, New Zealand, Norway, Czech Republic, Slovakia, India, China Mainland, ACP countries, Thailand and Former USSR.

In the model, these two markets are linked together through the Brazilian sugar and ethanol markets. In the Brazilian market, a "sugarcane allocation ratio variable" is defined as the relative proportions of sugarcane that go to ethanol production and sugar production. In recent years, mills have become more flexible, producing both sugar and ethanol at a single facility. The main driving factor that determines the production levels of sugar and ethanol is the relationship between the domestic sugar price and the domestic ethanol price. The reaction of producers to a change in market price is replicated in the model by means of an allocation ratio variable, which enables instantaneous ethanol and sugar production adjustment corresponding to the relative sugar-ethanol price ratio. In the US (the second largest ethanol producer in the world), ethanol is mostly produced from maize. Therefore, the model is also linked to the maize market through the exogenously defined maize price in the US ethanol market.

Each country market consists of production, consumption, exports, imports and ending stocks activities. The sugar market activities are defined on a raw sugar equivalent basis.

2) Model structures

The fundamental concept of our model is illustrated in the following chart (Figs. 1 and 2).

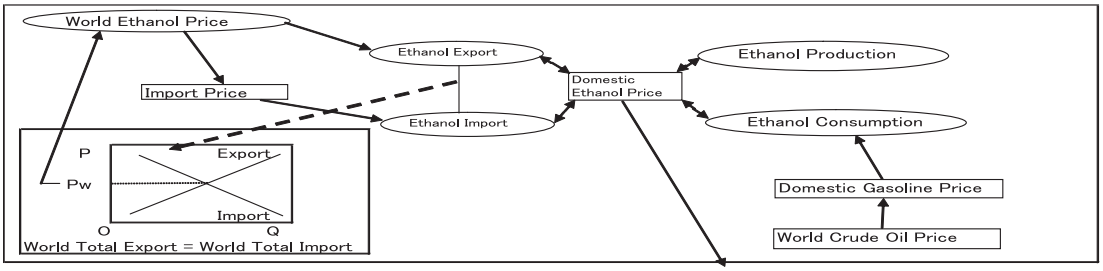

Figure 1. World ethanol model

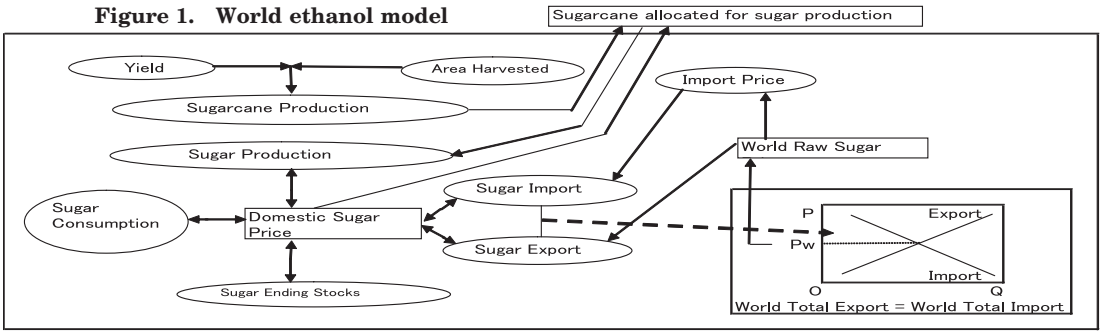

Figure 2. World suger model (raw suger equivalent)

(1) Ethanol sector

The ethanol sector is described by equations for production, per capita consumption, imports and exports equations. The ethanol production equation takes the following general form

$$QPE_{r,t} = QPE_{r,t-1} * ((DPE_{r,t}/DPE_{r,t-1})\hat{}a1, r * (WEP_t/WEP_{t-1})\hat{}a2, r) * (1 + a3, r)$$

where QPE is ethanol production, DPE is domestic ethanol price, WEP is world ethanol price, a1-a3 are parameters,[2] t is a time-index and r is an index assigned to each country and region. The symbol "^" means power. Each parameter was estimated by the authors and the estimates are reported in Appendix A. This equation form is applied to the cases where ethanol is produced from sugarcane. However, sugarcane is not the only source for the production of ethanol. In the U.S., for example, the production of ethanol comes mostly from maize. Ideally, the model specifications should be extended to cover these related agricultural commodity markets; however, at this stage of model development, the relevant markets are approximated by exogenously provided market prices. In countries producing ethanol from maize, ethanol production depends on the domestic price, ethanol producer price and maize producer price.

$$QPE_{r,t} = QPE_{r,t-1} * ((PPE_{r,t}/PPE_{r,t-1})\hat{}a4, r * (PPM_{r,t}/PPM_{r,t-1})\hat{}a5, r) * (1 + a3, r) \text{ or}$$

$$QPE_{r,t} = QPE_{r,t-1} * ((DPE_{r,t}/DPE_{r,t-1})\hat{}a1, r * (PPM_{r,t}/PPM_{r,t-1})\hat{}a5, r) * (1 + a3, r)$$

where PPM is producer price of maize, PPE is producer price of ethanol and a4-a5 are parameters. Ethanol production in Brazil is defined as a residual from sugarcane that was used for sugar production. The ethanol extraction ratio depends on technological growth.

$$QPE_t = ((AHS_t * YSC_t) - SUAL_t) * ERE_t$$
$$ERE_t = ERE_{t-1} * (1 + 0.001)$$

where AHS is area harvested, YSC is yield of sugarcane, SUAL is the sugarcane allocated for sugar production, ERE is ethanol extraction ratio and 0.001 is an econometrically estimated ethanol extraction efficiency growth rate in Brazil.

Per capita ethanol consumption depends on ethanol prices and income as are shown in the following three equations :

$$PQCE_{r,t} = PQCE_{r,t-1} * ((DPE_{r,t}/DPE_{r,t-1})\hat{}a6, r) * (DPG_{r,t}/DPG_{r,t-1})\hat{}a9) * (1 + a7, r) \text{ or}$$
$$PQCE_{r,t} = PQCE_{r,t-1} * ((I_{r,t}/I_{r,t-1})\hat{}a10, r) * ((MPE_{r,t}/MPE_{r,t-1})\hat{}a11, r) * (1 + a7, r) \text{ or}$$
$$PQCE_{r,t} = PQCE_{r,t-1} * ((PPE_{r,t}/PPE_{r,t-1})\hat{}a8) * (1 + a7, r)$$

where PQCE is the per capita consumption of ethanol, DPG is domestic gasoline price, MPE is an import price of ethanol, I is the per capita income and a6-a11 are the parameters. Total ethanol consumption is calculated by multiplying the per capita consumption by population :

$$QCE_{r,t} = PQCE_{r,t} * POP_{r,t}$$

where QCE is ethanol consumption.

Ethanol consumption in Brazil is specified as the sum of transportation use and other uses, where transportation use depends on domestic ethanol and gasoline prices, which are determined by the exogenously provided crude oil price and the number of vehicles. Anhydrous ethanol consumption depends on the blend ratio relative to gasoline. For other uses, per capita ethanol is calculated as described in the set of three equations already mentioned.

$$QCE_t = (QCG_t/(1 - BLEND)) * BLEND$$
$$QCG_t = PQCG_t * CARNUM_t$$
$$PQCG_t = PQCG_{t-1} * ((DPG_t/DPG_{t-1})\hat{} (-0.4152) * ((DPE_t/DPE_{t-1})\hat{} (-0.1218)) * (1 + 0.01)$$
$$DPG_t = DPG_{t-1} * (WOP_t/WOP_{t-1})\hat{}0.3363$$
$$CARNUM_t = \sum CARQP_{t-i,\, i=1,12}$$
$$CARQP_t = ((I_t/I_{t-1})\hat{}0.1379) * (1 + 0.001)$$

where QCE is ethanol consumption, QCG is gasoline consumption, BLEND is anhydrous ethanol blend ratio relative to gasoline, PQCG is per car consumption of gasoline, CARNUM is car number, WOP is world crude oil price and CARQP is Car Production. In the PQCG equation, −0.4152 is the estimated value of demand elasticity with respect to domestic gasoline price, −0.1218 is the price elasticity for domestic gasoline price, and 0.01 is the per capita demand growth ratio. In the DPG equation, 0.3363 is the price elasticity for world crude oil price. In the CARQP equation, 0.1379 is the elasticity with respect to the general economic growth and 0.001 is the growth rate of car production.

Two types of import and export equations are introduced to ensure the domestic market clearing condition. For a net importing country, exports are approximated by a price responsive behavioral equation : namely ethanol exports depend on the world ethanol price and domestic ethanol price as follows :

$$EXE_{r,t} = EXE_{r,t-1} * ((WEP_t/WEP_{t-1}\hat{}a12, r * (DPE_{r,t}/DPE_{r,t-1})\hat{}a13, r) * (1 + a14, r)$$

where EXE is ethanol exports and a12-a14 are parameters. For net exporting countries, exports are the exportable surplus remaining after domestic consumption has been satisfied.

$$EXE_{r,t} = QPE_{r,t} + IME_{r,t} - QCE_{r,t}$$

where IME is ethanol imports. Similarly, ethanol imports for a net exporting country are a function of import and domestic prices of ethanol, specified as follows :

$$IME_{r,t} = IME_{r,t-1} * ((MPE_{r,t}/MPE_{r,t-1}\hat{}a15, r * (DPE_{r,t}/DPE_{r,t-1}\hat{}a16, r) * (1 + a17, r)$$

where MPE is import price of ethanol and a15-a17 are parameters. Ethanol imports, for a net importing country, are defined as the market deficit remaining after domestic consumption has been satisfied.

$$IME_{r,t} = EXE_{r,t} + QCE_{r,t} - QPE_{r,t}$$

Domestic ethanol import price and producer price are linked to the world ethanol price as follows :

$$MPE_{r,t} = WEP_t * (1 + TE_{r,t})$$
$$PPE_{r,t} = PPE_{r,t-1} * (WEP_t/WPE_{t-1})\hat{}a18, r$$

where TE is the *ad valorem* tariff rate as reported to the WTO and a18 is a parameter.

(2) Sugar sector

Area harvested and yield equations determine the supply of sugar. Since sugar is produced from sugarcane and sugar beets in the US, EU15, Japan, and China, two separate supply equations are estimated for each of these countries. For other countries, one supply equation is estimated, either for sugarcane or sugar beet. Reflecting variations in production practices and market situations, sugar area harvested equations were estimated in differentiated ways and are specified such that the area depends on lagged sugar prices and alternative crop prices as follows :

$$AHS_{r,t} = AHS_{r,t-1}*((DPS_{r,t-1}/DPS_{r,t-2})\hat{}b1, r*(1+b2, r) \text{ or}$$
$$AHS_{r,t} = AHS_{r,t-1}*((DPS_{r,t-2}/DPS_{r,t-3})\hat{}b1, r*(1+b2, r) \text{ or}$$
$$AHS_{r,t} = AHS_{r,t-1}*((DPSB_{r,t-1}/DPSB_{r,t-2})\hat{}b3, r*((PPSA_{r,t-1}/PPSA_{r,t-2}))\hat{}b4, r*(1+b5, r) \text{ or}$$
$$AHS_{r,t} = AHS_{r,t-1}*((PPS_{r,t-1}/PPS_{r,t-2})\hat{}b6, r*((PPSA_{r,t-1}/PPSA_{r,t-2}))\hat{}b4, r*(1+b5, r) \text{ or}$$
$$AHS_{r,t} = AHS_{r,t-1}*((PPS_{r,t-2}/PPS_{r,t-3})\hat{}b6, r*(1+b5, r) \text{ or}$$
$$AHS_{r,t} = AHS_{r,t-1}*((WPS_{r,t-1}/WPS_{r,t-2})\hat{}b7, r*(1+b5, r) \text{ or}$$
$$AHS_{r,t} = AHS_{r,t-1}*((WPS_{r,t-2}/WPS_{r,t-3})\hat{}b7, r*(1+b5, r)$$

where AHS is area harvested, DPS is domestic price of sugar, DPSB is domestic price of sugar beet, PPS is producer price of sugar, PPSA is a producer price of alternative crop, WPS is world price of sugar, and b1-b7 are parameters.

It is assumed that sugarcane yield, sugar beet yield, and sugar extraction ratio depend on the technological growth ratio as follows :

$$YSC_{r,t} = YSC_{r,t-1}*(1+b8, r) \text{ or}$$
$$YSB_{r,t} = YSB_{r,t-1}*(1+b9, r)$$
$$ERS_{r,t} = ERS_{r,t-1}*(1+b10, r)$$

where YSC is sugarcane yield, YSB is yield of sugar beet yield, b8-b10 are parameters and ERS is sugar extraction ratio of sugar. Sugar production is explained as follows, except for Brazil, ACP countries[3] and the rest of the world :

$$QPS_{r,t} = (AHSC_{r,t}*YSC_{r,t} + AHSB_{r,t}*YSB_{r,t})*ERS_{r,t}$$

where QPS is sugar production. For the Brazilian sugar market, the allocation ratio for sugar is a crucial factor in determining the sugar production. Thus, sugar production in Brazil is defined by the following two equations :

$$SUAL_t = (AHSC_t*YSC_t)*(0.3 + 0.18*((DPS_t/DPS_{t-1})/(DPE_t/DPE_{t-1})))$$
$$QPS_t = SUAL_t*ERS_{,t}$$

where SUAL is the sugarcane allocated for sugar production, 0.3 explains a fixed proportion of sugarcane allocated for sugar production and 0.18 is a factor of change in allocation when a relative sugar or ethanol price changes. In Brazil, the juice extracted from sugarcane is allocated to either sugar or ethanol. The allocation of sugarcane for sugar or for the ethanol production is determined by the sugar-ethanol price ratio[4].

Per capita sugar consumption depends on the sugar prices and income.

$$PQCS_{r,t} = PQCS_{s,t-1}*((DPS_{r,t}/DPS_{r,t-1})\hat{}b11, r)*((I_{r,t}/I_{r,t-1})\hat{}b12, r)*(1+b13, r) \text{ or}$$
$$PQCS_{r,t} = PQC_{r,t-1}*((PPS_t/PPS_{t-1})\hat{}b14)*((I_{r,t}/I_{r,t-1})\hat{}b12, r)*(1+b13, r) \text{ or}$$
$$PQCS_{r,t} = PQCS_{r,t-1}*((MPS_t/MPS_{t-1})\hat{}b15)*((I_{r,t}/I_{r,t-1})\hat{}b12, r)*(1+b13, r) \text{ or}$$
$$PQCS_{r,t} = PQCS_{r,t-1}*((CPIS_{r,t}/CPIS_{r,t-1})\hat{}b16, r)*((I_{r,t}/I_{r,t-1})\hat{}b12, r)*(1+b13, r)$$

where PQCS is per capita consumption of sugar, I is per capita income, MPS is import price of sugar, CPIS is consumer price of sugar and b11-b16 are parameters. Per capita income and CPIS are exogenous variables obtained from the WEFA group and OECD. Total sugar consumption is calculated by multiplying the per capita consumption by the country's population :

$$QCS_{r,t} = PQCS_{r,t}*POP_{r,t}$$

where QCS is sugar consumption and POP is population.

Brazilian and US sugar exports depend on world sugar prices and domestic sugar prices as follows :

$$EXS_{r,t} = EXS_{r,t-1}*((WPS_{r,t}/WPS_{r,t-1})\hat{}b17, r*(DPS_{r,t}/DPS_{r,t-1})\hat{}b18, r)*(1+b19, r)$$

where EXS is sugar exports, WPS is world raw or white sugar price and b17, b18 and b19 are parameters. For a net sugar-exporting country, exports are the exportable domestic market balance deficit after domestic consumption has been satisfied.

$$EXS_{r,t} = QPS_{r,t} + IMS_{r,t} - QCS_{r,t} - (SS_{r,t} - SS_{r,t-1})$$

where IMS is sugar imports and SS is ending stock of sugar.

Sugar imports in a net sugar-exporting country depend on import sugar prices and domestic prices as follows :

$$IMS_{r,t} = IMS_{r,t-1} * ((MPS_{r,t}/MPS_{r,t-1})\hat{}\,b20, r * (DPS_{r,t}/DPS_{r,t-1})\hat{}\,b21, r) * (1 + b22, r)$$

where b20-b22 are parameters. For other net sugar-importing countries, imports are the market balance deficit remaining after domestic consumption has been satisfied.

$$IMS_{r,t} = EXS_{r,t} + QCS_{r,t} + (SS_{r,t} - SS_{r,t-1}) - QPS_{r,t}$$

EU15 adopts the special preferential treatments for specified countries by allocating a certain amount of import quotas. Except for special preferential treatments, EU15 adopts restricted import measures for all other countries. Their imports depend on the world raw sugar price and domestic price as follows :

$$IMS_{r,t} = IMS_{r,t-1} * ((WPS_t/WPS_{t-1})\hat{}\,b23 * (DPS_{r,t}/DPS_{r,t-1})\hat{}\,b24) * (1 + b22, r)$$

where b23-b24 are parameters.

Sugar ending stocks are related to the level of production and sugar prices in a sugar-exporting country as follows :

$$SS_{r,t} = SS_{r,t-1} * ((QPS_{r,t}/QPS_{r,t-1})\hat{}\,b25, r) * ((DPS_{r,t}/DPS_{r,t-1})\hat{}\,b26, r) * (1 + b27, r) \text{ or}$$

$$SS_{r,t} = SS_{r,t-1} * ((QPS_{r,t}/QPS_{r,t-1})\hat{}\,b25, r) * ((WPS_{r,t}/WPS_{r,t-1})\hat{}\,b28, r) * (1 + b27, r) \text{ or}$$

$$SS_{r,t} = SS_{r,t-1} * ((QPS_{r,t}/QPS_{r,t-1})\hat{}\,b25, r) * ((PPS_{r,t}/PPS_{r,t-1})\hat{}\,b29, r) * (1 + b27, r)$$

where b25-b29 are parameters.

For a sugar-importing country, ending stocks related to the level of consumption and sugar prices as follows :

$$SS_{r,t} = SS_{r,t-1} * ((QCS_{r,t}/QCS_{r,t-1})\hat{}\,b30, r) * ((DPS_{r,t}/QPS_{r,t-1})\hat{}\,b26, r) * (1 + b27, r) \text{ or}$$

$$SS_{r,t} = SS_{r,t-1} * ((QCS_{r,t}/QCS_{r,t-1})\hat{}\,b30, r) * ((MPS_{r,t}/MPS_{r,t-1})\hat{}\,b31, r) * (1 + b27, r)$$

where b30-b31 are parameters.

(3) World market equilibrium and price linkage

For each simulation year and each commodity, the model determines gross exports and imports for each country and region. A world market equilibrium price is then obtained from the following equilibrium condition through the use of the Gauss-Seidel algorithm. World sugar price refers to the world raw sugar market clearing price and world ethanol price refers to the world ethanol market clearing price.

$$\sum_r EX_{i,r,t} = \sum_r IM_{i,r,t}$$

where i is either sugar or ethanol and r is each country and region.

Because several country markets are subject to strong governmental market interventions, their country market-clearing prices are obtained from the country market clearing identities in three different ways : (1) by assuming perfect isolation in the domestic market price movement from the world price, (2) by assuming an imperfect linkage to the world price, and (3) by assuming a domestic market price movement co-integrated with the world price. Among the 23 sugar country markets, prices in the EU15 and Japanese markets are almost perfectly isolated from world market-price movements, because these two countries and regions have adopted a variable or quasi-variable levy system for imported sugar. Their governmental prices guide domestic supply and consumption, with trade filling supply-consumption gaps. Domestic prices in EU15 and Japan are set in order to support targeted production. These prices are taken from exogenous data (see Appendix B, Table B1).

In contrast, the domestic market prices in Brazil, the U.S., and India are assumed to follow world price movements in a limited sense. The government establishes domestic market price guidelines, such as the Central Issue Price (CIP) for sugar in India. Most of the guidelines aren't directly linked to world prices ; in the model, the price linkage equations are approximations that assume implicit links between domestic prices and the world price through indirect channels (such as an energy price linkage with production input price). The third type of market-clearing mechanism follows the standard treatment of world price transmission in a small-country setting.

The number of market-clearing conditions is the same as the number of domestic equilibrium prices. Each domestic market price is obtained by finding the corresponding market equilibrium price. The first two of the three mechanisms of domestic market clearing are

different from current models, such as the World Food Model (FAO), IFPSIM Model (Ministry of Agriculture, Forestry and Fisheries of Japan), AGLINK Model (OECD), IMPACT Model (IFPRI), CPPA (U.S. Department of Agriculture) and others, because all the domestic market prices in current models are assumed to have direct links to the world price. Although our model does not explicitly specify the relevant policy variables that determine the "guided domestic prices", characteristics of these unique "country sugar and ethanol markets" are expressed by introducing the different types of domestic price determination mechanisms, including the domestic price assumed to be totally isolated from the world price.

World white sugar price, domestic sugar import price, and domestic producer price are each linked to the world raw sugar price through constant price transmission elasticity as follows :.

$$WHP_t = (WRP_t/WRP_{t-1})\hat{}0.9345$$
$$MPS_{r,t} = WRP_t*(1 + TS_t)$$
$$PPS_{r,t} = PPS_{r,t-1}*(WRP_t/WRP_{t-1})\hat{}b32,r$$

where WHP is world white sugar price, WRP is world raw sugar price, TS is the *ad valorem* tariff ratio for sugar, b32 is a parameter and 0.9345 is the elasticity of price transmission from the world raw sugar price to the world refined sugar price.

Data for the sugar and ethanol markets are taken from FAOSTAT. Brazilian ethanol and automobile data have been collected from publications issued by the government of Brazil.

3. Projections

1) Assumptions

Our baseline simulation was based on a series of assumptions about the general economy, agricultural policies, and technological changes in the exporting and importing countries during the projection period. The exogenous assumption regarding projected demand for gasoline in India was taken from *World Energy Outlook 2002* [6]. Another exogenous assumption, the projected world crude oil price, was derived from U. S. Department of Energy's *Annual Energy Outlook 2003* [11]. In this USDE-baseline scenario, the world crude oil price is expected to increase at a rate of 0.9% per year from 2001 to 2010. Gasoline consumption data in major Indian cities were derived from publications issued by the government of India. Exogenous sugar domestic prices were taken from OECD [9]. Population data for all countries were taken from official U.N. population estimates. GDPs were also treated as exogenous variables and their growth rate assumptions were mainly based on World Bank economic forecasts.

We also assumed that current agricultural policies will continued in all countries throughout the projection period. Following the generally adopted procedures, we assumed normal weather and historical rates of technological innovation, New WTO agricultural agreements were not taken into account in the models. Market access and export subsidies were frozen at levels prevailing in the year 2000 for developed countries and 2004 for developing countries. Regional free trade areas were assumed not to expand. The entry of China and Taiwan Province into the WTO was taken into account in calibrating the baseline estimates. We assumed that Brazil will maintain its ethanol program and the ethanol blend ratio will remain at a maximum level of 25% throughout the projection period. The government of India was assumed to begin implementing its E-5 program (5% ethanol, 95% unleaded gasoline) in four major cities in 2003.[5)]

2) Projected world and Brazilian ethanol markets to the year 2010

World ethanol consumption is projected to increase by 2.5% per annum from 2001 to 2010. As a result of the conversion from MTBE (Methyl Tertiary Butyl Ether) to ethanol in the U.S. fuel market, U.S. ethanol consumption is projected to follow a step-shaped increase. The world ethanol price, is predicted to increase in a fluctuating manner during 2001-2010, reaching about 1.13 in 2010 in terms of a created price index (2001=1). Because it is natural to assume that most ethanol-producing countries will give priority to domestic markets in supplying their products, the baseline is evicted by a scenario in which world ethanol trade will not occupy an expanding share relative to production and consumption. Relative to production, trade will still be 10.0% in 2010. World ethanol ex-

ports are projected to increase by 1.4% per annum during this period. Since the relatively high domestic and international prices of ethanol are expected to stimulate production, world ethanol production is projected to grow by 2.5% per annum.

Brazil's ethanol consumption is projected to increase by 1.5% per annum, occupying a dominant 48.6% share of world ethanol demand in 2010, based on the assumption of continued imposition of the anhydrous ethanol-blend ratio of 25%. Since gasoline consumption in Brazil is predicted to increase by 2.5% per year, consumption of anhydrous ethanol should increases proportionately, while hydrated ethanol and anhydrous ethanol for other uses are projected to decrease by 1.4% per annum. Ethanol production in Brazil is projected to increase by 1.6% per annum during this decade. It is further assumed that the government of Brazil will adhere to the purpose of its ethanol program and give priority to meeting domestic demand rather than joining the global markets. Brazil's ethanol exports are predicted to increase by only 3.2% per annum during this period.

We assumed that India will implement the E-5 program in four major cities. Reflecting this assumption, ethanol consumption and production in India are projected to increase by 1.9% per annum during this period.

In the U.S., the use of MTBE is expected to be in force in 14 states that have passed relevant legislation.[6] Consequently, U.S. ethanol consumption is projected to expand by 5.2% per annum during this period. Despite the estimated higher ethanol demand, the domestic ethanol producer price is projected to decrease from 169.7 to 157.8 (index 1982=100) during this period. US ethanol production is projected to increase by 5.1% per annum, slightly less than the rise in consumption, but ethanol exports are projected to decrease by 2.2% per annum.

Total ethanol consumption by OECD countries is projected to increase by 4.2% per annum during this period, and their production will increase by 4.5% per annum. US market developments greatly influence the markets in OECD countries.

3) Projected world and Brazilian sugar markets to the year 2010

World sugar production (in raw sugar equivalent) is projected to expand by 2.1% per annum from 2001 to 2010. The country that contributes most to this increase in world sugar production is Brazil. World sugar consumption is projected to expand by 2.0% per annum during this period, with India contributing most. World sugar exports (raw sugar equivalent) are projected to increase by 1.4% per annum during this period. The world raw sugar price[7] was 8.64 USC/lb in 2001 and is expected to follow cyclic fluctuations during the projection period because of the inevitable time lag involved in sugarcane production. The world price in the year 2010 is projected at 5.85 USC/lb.

Brazil's sugarcane production is predicted to increase by 1.5% per annum during the 2001-2010 period, supported by projected steady growth in area harvested and yield. The area harvested is projected to increase by 0.5% per annum. The sugarcane area harvested in Brazil amounts to about 10.6% of the total crop area harvested. Sugarcane yield is predicted to increase by 1.0%.

From 2009 to 2010, Brazil's domestic sugar price is projected to decrease from 0.895 to 0.859 (index 2000=1)[8] and its domestic ethanol price to decrease from 0.978 to 0.935.[9] The price ratio, which is calculated as the ratio of the normalized sugar price divided by the normalized ethanol price, is projected to increase from 0.915 to 0.919. This is the major cause of incentive for the increase of sugar production. With this change in the producer price ratio, sugarcane allocated for sugar production is projected to increase from 49.3 to 49.5 in 2010.

Brazil's sugar production is predicted to increase by 2.5% per annum during this period. Exports are predicted to grow by 1.8% per annum. Brazil is expected to be the largest sugar exporter in the world by 2010.

EU15's sugar production is derived from both sugar beets and sugarcane. Their production is projected to increase by 1.7% per annum from 2001 to 2010, with exports decreasing by 1.1% per annum from 2001 to 2010. Total OECD sugar production is projected to increase by 2.0% per annum, with their exports increasing by 1.5% per annum during

this period.

4. Impacts of Brazilian Government Blend Ratio Selection on the World Sugar Market

1) Imposed alternative scenario

The notion of substituting ethanol for diesel oil in diesel cycle engines has been considered and evaluated since the late 1970s. At the experimental level, anhydrous ethanol was blended with diesel oil at 8% in Brazil. The same experiment was undertaken earlier in Sweden and the U.S. but each adopted a blend ratio of 15%. The repercussions of increasing ethanol demand are vast, even though the government of Brazil does not yet blend anhydrous ethanol blend with diesel oil. Because the upper limit of the anhydrous ethanol blend ratio is set at 26%, current policy allows very little room for expanding anhydrous ethanol consumption by increasing the blend ratio in gasoline. To increase domestic ethanol consumption and control the sugar market more effectively, implementing an anhydrous ethanol-diesel blend ratio seems to be necessary.

As an alternative scenario to this study, we assumed that the government imposes a further restriction on the anhydrous ethanol blend ratio to domestic diesel oil, after the technology becomes commercially available. This program is assumed to start in 2006, with the blend ratio set at 8%.

2) Impacts on the ethanol market

Diesel oil consumption in Brazil is projected to increase by 2.2% per annum from 2001 to 2010. In 2006, the consumption is projected to be 26.2 million tons. Assuming the anhydrous ethanol-diesel blend is imposed, Brazil's ethanol consumption is predicted to increase by 15.7% in 2010 (Table 2). In 2010, its consumption is predicted to occupy a dominant 55.5% share of world ethanol consumption. Due to the higher consumption, its domestic ethanol price is predicted to increase by 4.7% (Table 5). Production of ethanol is flexibly adjustable to the extent that sugarcane can be diverted from for sugar production without a time lag. We assumed that producers can adjust their ethanol-sugar production mix by allocating as much of 22% of the total domestic sugarcane supply as an adjustable input, which is already a standard business practice. Assuming this capability continues, Brazil's ethanol production is predicted to increase by 15.3% in 2010 (Table 1). Like other ethanol-producing countries, Brazil is expected to give priority to supplying its domestic market, rather than increasing its exports in response to the increased word market price ; therefore, Brazil's ethanol exports are predicted to decrease by 3.0% in 2010 (Table 3).

World ethanol consumption and production are both predicted to increase by 8.3% in 2010 (Tables 1 and 2). The volume of world ethanol trade is predicted to decrease by 0.10 % (Tables 3 and 4), and the world ethanol price is predicted to increase by 0.9% (Table 5).

3) Impacts on the sugar market

As a result of the higher domestic ethanol price, Brazilian sugar production is predicted to shift from sugar to ethanol production. In 2006, the domestic ethanol price is predicted to be much higher than the domestic sugar price in Brazil. The price ratio is predicted to be 0.892, in contrast to a ratio of 0.905 in the baseline projection. As a result, the allocation ratio for sugar is predicted to decrease from 48.17 to 46.97% in 2006. The price ratio is predicted to diminish gradually during the 2006-2010 period. The allocation ratio for sugar production is predicted to be 48.16% in 2010, compared to 49.51% in the baseline case. Brazil's sugar production is predicted to decrease by 2.4% in 2010 (Table 6), with exports predicted to decrease by 2.9% (Table 8).

Brazil's domestic sugar price is expected to increase by 5.5% in 2010 (Table 10). On account of this shift in sugarcane allocation from sugar to ethanol production in Brazil, world sugar production is predicted to decrease by 0.2% (Table 6), with world sugar exports predicted to decrease by 0.3% compared to the baseline case (Table 8). As a result, the world raw sugar price is predicted to increase by 3.5% (Table 10).

5. Conclusion

As a result of the Brazilian imposition of a further 8% anhydrous ethanol blended into diesel oil beginning in 2006, world ethanol and sugar prices are predicted to increase. Our estimate results indicate that the magnitudes of the world price hikes for both sugar and ethanol are moderate but will persist for

Table 1. Impacts on world ethanol production

	Scenario/Baseline
World total	8.3%
Brazil	15.3%

Table 2. Impacts on world ethanol consumption

	Scenario/Baseline
World total	8.3%
Brazil	15.7%

Table 3. Impacts on world ethanol export

	Scenario/Baseline
World total	−0.1%
Brazil	−3.0%

Table 4. Impacts on world ethanol import

	Scenario/Baseline
World total	−0.1%
Brazil	2.3%

Table 5. Impacts on ethanol prices

	Scenario/Baseline
World	0.9%
Brazilian fuel anhydrous ethanol (State of São Paulo)	4.7%

Table 6. Impacts on world sugar production

	Scenario/Baseline
World total	−0.2%
Brazil	−2.4%
OECD countries total	0.2%
Australia	0.7%
ACP countries	0.8%
Thailand	0.7%

Table 7. Impacts on world sugar consumption

	Scenario/Baseline
World total	−0.2%
Brazil	−1.3%
OECD countries total	−0.2%

Table 8. Impacts on world sugar export

	Scenario/Baseline
World Total	−0.3%
Brazil	−2.9%
OECD countries total	0.5%
Australia	0.6%
ACP countries	1.6%
Thailand	1.2%

Table 9. Impacts on world sugar import

	Scenario/Baseline
World total	−0.3%
Brazil	1.4%
OECD countries total	−0.1%
U.S.	0.0%
Japan	0.0%

Table 10. Impacts on sugar prices

	Scenario/Baseline
World (I.S.A average price)	3.5%
Brazilian crystal sugar	5.5%

years.

Although Brazil's sugar exports are predicted to decrease, world sugar exports are predicted to remain at the baseline predicted level because the higher world sugar price will stimulate major sugar-exporting countries to increase their exports from 2006 onward. A higher raw sugar trade price will benefit other sugar-exporting countries, too. Other sugarcane-based sugar exporters are expected to materialize benefits with a two-year time lag because of the agricultural conditions associated with sugarcane growing. Exports from the ACP countries are predicted to increase by 1.6%. Because most of the ACP economies depend heavily on sugar exports, the higher world sugar price could be beneficial to them. Exports from Thailand and Australia are predicted to increase by 1.2% and 0.6%, respectively.

The government of Brazil may control not only domestic sugar and ethanol markets, but also world sugar and ethanol prices. They abolished most of their regulations for domestic sugar and ethanol markets in the 1990s. There is no regulation at present, except for the setting of the anhydrous ethanol-gasoline blend ratio.

Simulated policy changes on the part of the Brazilian Ethanol Program have affirmed that the Brazilian government can control its sugar output and export. It also lead to a situation in which world sugar price are heavily impacted by the Brazilian program. Setting a

further anhydrous ethanol blend ratio for diesel may be an effective policy tool for controlling domestic and world sugar markets, and the program will also contribute to expanding domestic ethanol markets. In addition, the program will lead to a reduction in oil imports, with 23.2-25.8 million metric tons of oil import expected to be saved. However, Brazilian consumers may have to pay a higher fuel price for diesel fuel. Further study is needed to examine how large the consumer loss will be when the government adopts the imposition of further anhydrous ethanol-diesel blend. Future directions for this study include examining the consumer loss that results from applying this program.

1) Data are derived from Ministry of Mines and Energy, Secretariat for Energy of Brazil, *Brazilian Energy Balance 2000*.
2) Refer to appendix A. As for evaluation of each parameter, refer to appendix C. Our model is a policy simulation model and we deem that each equation is necessary and the magnitude of each parameter is reasonable for building this model. Because, their *t*-values are not high, we provide appendix C to enable the reader to understand the model structure more clearly.
3) In this paper, the ACP consist of 70 countries, excluding South Africa.
4) This price ratio is calculated as (domestic sugar price)/(domestic ethanol price).
5) The four cities are Delhi, Calcutta, Mumbai and Bangalore.
6) Arizona, California, Colorado, Connecticut, Indiana, Iowa, Illinois, Kansas, Michigan, Minnesota, Nebraska, New York, South Dakota and Washington.
7) In terms of the I.S.A average price.
8) The domestic sugar price is projected to decrease from 18.97 to 18.18 Real/50 kg.
9) The domestic ethanol price is projected to decrease from 556.11 to 532.06 R $/1,000 liters.

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Appendix A ; Estimated parameters

Table A1. Ethanol sector

Coefficients	a1	a2	a3	a4	a5	a6	a7	a8	a9
Dependent variables	Ethanol production					Per capita ethanol consumption			
Explanatory variables	Domestic price of ethanol	World ethanol price	Growth ratio	Producer price of ethanol	Producer price of maize	Domestic price of ethanol	Growth ratio	Producer price of ethanol	Domestic price of gasoline
Brazil	–	–	–	–	–	−0.3708	−0.0420	–	–
USA	0.6854	–	0.0610	–	−0.2131	−0.4426	0.0490	–	−0.4426
EU15	0.3379	0.1700	0.0280	–	–	−0.2092	0.0150	–	–
Mexico	–	–	0.0040	0.3051	–	–	0.0050	–	–
Japan	–	–	–	–	–	–	0.0220	–	–
Korean Republic	–	–	–	–	–	–	0.0120	–	–
Canada	–	–	–	–	–	–	0.0070	–	–
Hungary	–	0.1892	0.0120	–	–	–	0.0170	–	–
Poland	–	0.1503	0.0150	–	–	–	0.0120	–	–
Switzerland	–	0.1413	0.0100	–	–	–	0.0100	–	–
Turkey	–	0.0974	0.0251	–	–	–	0.0170	–	–
New Zealand	–	0.1413	0.0100	–	–	–	0.0100	–	–
Norway	–	0.1767	0.0160	–	–	–	0.0140	–	–
Czech Republic	–	0.2852	0.0130	–	–	–	0.0100	–	–
Slovakia	–	0.1591	0.0100	–	–	–	0.0100	–	–
India	0.3219	0.0150	0.0170	–	–	−0.1009	0.0020	–	–
China, Mainland	–	–	0.0100	0.3254	−0.1898	–	0.0100	−0.2037	–
ACP countries	–	–	0.0200	0.3051	–	–	0.0030	–	–
Thailand	–	–	0.0080	0.2014	–	–	−0.0090	–	–
Former USSR	–	0.2119	0.0150	–	–	–	0.0070	–	–
Rest of the world	–	0.4251	0.0240	–	–	–	0.0001	–	–

Coefficients	a10	a11	a12	a13	a14	a15	a16	a17	a18	T
Dependent variables	Per capita ethanol consumption		Ethanol export			Ethanol import			Producer price	Import price
Explanatory variables	Per capita income	Import price of ethanol	World ethanol price	Domestic price of ethanol	Grwoth ratio	Import price of ethanol	Domestic price of ethanol	Growth ratio	Producer price transmission elasticity	Ad valorem,tariff ratio
Brazil	0.2956	–	0.317529	−0.704744	0.0180	−0.2787	0.54874	−0.0100	–	0.3500
USA	–	–	0.233105	−0.57195	−0.0320	−0.1459	0.36116	0.0230	–	0.0190
EU15	–	–	0.434379	−0.1334379	0.0210	−0.1856	0.36926	0.0055	–	0.3200
Mexico	0.1848	–	0.11314	–	0.0110	–	–	–	0.1381	–
Japan	0.3374	−0.3183	–	–	–	–	–	–	–	0.2720
Korean Republic	0.4279	−0.3121	0.2916	–	0.0100	–	–	–	–	0.0800
Canada	0.1513	–	0.2896		0.0100	–	–	–	–	–
Hungary	0.1203	–	–	–	–	−0.2028	–	0.0100	–	1.0200
Poland	0.1271	–	–	–	–	−0.1459	–	0.0100	–	–
Switzerland	0.1125	–	0.1053		0.0100	–	–	–	–	–
Turkey	0.1230	–	–	–	–	−0.1459	–	0.0100	–	1.0200
New Zealand	0.1914	–	–	–	–	−0.1459	–	0.0100	–	0.0320
Norway	0.1155	–	–	–	–	–	–	–	–	–
Czech Republic	0.1278	–	–	–	–	−0.1459	–	0.0100	–	0.5950
Slovakia	0.1278	–	–	–	–	–	–	–	–	–
India	–	–	0.1331	−0.1751	0.0130	−0.1787	0.24874	0.0100	–	1.5000
China, Mainland	–	–	–	–	–	–	–	0.0100	0.1877	1.6000
ACP countries	0.1019	–	0.1131	–	0.0210	–	–	–	0.1381	–
Thailand	0.2495	–	0.1957	–	0.0110	–	–	–	0.3381	–
Former USSR	0.2959	–	0.2503	–	0.0100	–	–	–	–	–
Rest of the world	–	–	0.2503	–	0.0001	–	–	–	–	–

Note : "—" means "do not apply to the countries or regions."

Table A2. Sugar sector

Coefficients	b1	b2	b3	b4	b5	b6	b7	b8	b9	b10	b11	b12
Dependent variables	Area harvested, sugar							Sugar yield		Sugar production	Per capita sugar consumption	
Explanatory variables	Domestic price of sugarcane	Sugarcane area harvested, growth ratio	Domestic price of sugar beet	Producer price of alternative crop	Growth ratio	Producer price of sugarcane	World raw or white sugar price	Technological growth ratio, sugarcane	Technological growth ratio, sugar beet	Sugar extraction ratio	Domestic price of sugar	Per capita income
Brazil	0.3259	0.0100	–	–	–	–	–	0.0110	–	0.0130	−0.2443	0.2513
USA	0.2443	0.0050	0.2092	−0.1173	0.0010	–	–	0.0034	0.0015	0.0016	−0.3470	0.1620
EU15	0.5073	0.0092	0.2711	−0.1667	0.0052	–	–	0.0099	0.0095	0.0010	−0.2932	0.2478
Australia	–	0.0080	–	–	–	0.2951	–	0.0022	–	0.0009	–	0.3007
Mexico	–	0.0060	–	–	–	0.1593	–	0.0060	–	0.0051	–	0.1858
Japan	0.3338	0.0010	0.2163	–	0.0050	–	–	−0.0001	−0.0001	−0.0080	−0.0554	0.1543
Korean Republic	–	–	–	–	–	–	–	–	–	–	–	–
Canada	–	–	–	–	–	–	0.2850	–	0.025	0.0100	–	0.2236
Hungary	–	–	–	–	–	–	0.2709	–	0.007	0.0110	–	0.3974
Poland	–	–	–	–	–	–	0.2332	–	0.008	0.0110	–	0.2488
Switzerland	–	–	–	–	–	–	0.2347	–	0.015	0.0120	–	0.2516
Turkey	–	–	–	–	–	–	0.2754	–	0.032	0.0120	–	0.3770
New Zealand	–	–	–	–	–	–	–	–	–	–	–	0.2442
Norway	–	–	–	–	–	–	–	–	–	–	–	0.1461
Czech Republic	–	–	–	–	–	–	0.1092	–	0.004	0.0130	–	0.1520
Slovakia	–	–	–	–	–	–	0.2964	–	0.004	0.0130	–	0.1255
India	0.2754	0.0110	–	–	–	–	–	0.0032	–	0.0036	−0.2414	–
China, Mainland	–	0.0060	–	−0.3269	0.0211	0.3839	–	0.0076	0.0163	0.0015	–	0.2738
Cuba	–	0.0030	–	–	–	0.2663	–	−0.0100	–	0.0033	–	0.2310
ACP countries	–	0.0328	–	–	–	–	0.2933	–	–	–	–	0.3785
South Africa	–	0.0040	–	–	–	0.2993	–	0.0230	–	0.0042	–	0.1723
Thailand	–	0.0150	–	–	–	0.3257	–	0.0257	–	−0.0010	–	0.2172
Fomer USSR	–	0.0380	–	–	–	–	0.2360	–	0.0265	−0.0010	–	0.3786
Rest of the world	–	0.0245	–	–	–	–	0.2933	–	–	–	–	–

Coefficients	b13	b14	b15	b16	b17	b18	b19	b20	b21	b22	b23	b24
Dependent variables	Per capita sugar consumption				Sugar export			Sugar import				
Explanatory variables	Growth ratio	Producer price of sugar	Import price of sugar	Consumer price	World raw or white sugar price	Domestic price of sugar	Growth ratio	Import price of sugar	Domestic price of sugar	Growth ratio	World raw sugar price	Domestic price of sugar, resriction import
Brazil	0.0010	–	–	–	0.3718	−0.7081	0.0150	−0.3641	0.2405	0.0040	–	–
USA	0.0025	–	–	–	0.4978	−0.2906	0.0130	–	–	–	–	–
EU15	−0.0010	–	–	–	–	–	–	–	0.1287	0.0360	−0.2333	0.6057
Australia	0.0150	–	–	−0.2853	–	–	–	−0.1130	–	0.0030	–	–
Mexico	−0.0050	–	−0.0729	–	–	–	–	−0.1109	–	0.0151	–	–
Japan	0.0020	–	–	–	–	−0.3346	−0.0020	–	–	–	–	–
Korean Republic	0.0220	–	–	−0.2079	0.1941	–	0.0140	–	–	–	–	–
Canada	0.0060	–	–	–	0.2260	–	0.0100	–	–	–	–	–
Hungary	−0.0010	–	–	–	–	–	–	−0.2072	–	0.0100	–	–
Poland	−0.0040	–	–	–	–	–	–	−0.2628	–	0.0100	–	–
Switzerland	−0.0010	–	–	–	0.1731	–	0.0100	–	–	–	–	–
Turkey	0.0159	–	–	–	–	–	–	−0.1828	–	0.0100	–	–
New Zealand	0.0140	–	–	–	0.3442	–	0.0100	–	–	–	–	–
Norway	−0.0010	–	–	–	0.4873	–	0.0120	–	–	–	–	–
Czech Republic	0.0130	–	–	–	–	–	–	−0.0617	–	0.0100	–	–
Slovakia	0.0030	–			0.1527	–	0.0100	–	–	–	–	–
India	0.0290	–	–	–	–	–	–	−0.1968	0.2405	0.0092	–	–
China, Mainland	0.0100	–	–	–	0.3112	–	0.0450	–	–	–	–	–
Cuba	0.0030	−0.3735	–	–	–	–	–	–	–	–	–	–
ACP countries	−0.0010	–	–	–	–	–	–	−0.3152	–	0.0010	–	–
South Africa	−0.0050	–	–	−0.4883	–	–	–	−0.3532	–	0.0010	–	–
Thailand	0.0300	–	–	–	–	–	–	−0.1130	–	0.0150	–	–
Fomer USSR	0.0200	–	–	–	0.1753	–	0.0020	–	–	–	–	–
Rest of the world	−0.0010	–	–	–	0.278641	–	0.0300	–	–	–	–	–

Coefficients	b25	b26	b27	b28	b29	b30	b31	b32	T
Dependent variables	Ending stock of sugar							Producer price	Import price
Explanatory variables	Sugar production	Domestic price of sugar	Growth ratio	World raw or white sugar price	Producer price of sugar	Sugar consumption	Import price of sugar	Producer price transmission elasticity	Ad valorem, tariff ratio
Brazil	0.1386	−0.2320	0.0010	–	–	–	–	–	0.3500
USA	–	−0.1185	0.0010	–	–	−0.1091	–	–	0.2580
EU15	0.1989	−0.2551	−0.0050	–	–	–	–	–	–
Australia	0.2555	–	−0.0070	−0.3068	–	–	–	0.8619	0.0800
Mexico	0.1514	–	−0.0270	–	−0.1522	–	–	0.5694	1.5600
Japan	–	−0.1039	−0.0001	–	–	–	–	–	–
Korean Republic	–	–	0.0010	−0.2379	–	0.4116	–	–	–
Canada	–	–	−0.0350	–	–	0.1091	−0.1184	–	–
Hungary	0.1091	–	0.0100	0.2551	–	–	–	–	0.6690
Poland	–	–	0.0180	–	–	0.1090	−0.1184	–	0.9600
Switzerland	–	–	0.0180	–	–	0.1091	−0.11846	–	0.6020
Turkey	0.1989	–	0.0050	−0.2551	–	–	–	–	1.3500
New Zealand	0.1988	–	0.0180	−0.2551	–	–	–	–	–
Norway	–	–	−0.0020	–	–	0.1091	−0.1185	–	0.4130
Czech Republic	0.1988	–	0.0210	−0.2551	–	–	–	–	0.6070
Slovakia	–	–	0.0350	–	–	0.1091	−0.1185	–	0.6120
India	0.1713	−0.1785	−0.0090	–	–	–	–	–	1.5000
China, Mainland	–	–	0.0150	–	–	0.2158	−0.1633	0.3141	0.3000
Cuba	0.1514	–	−0.0010	−0.1015	–	–	–	0.5177	–
ACP countries	0.1456	–	−0.0010	−0.2026	–	–	–	–	0.4000
South Africa	0.3456	–	−0.0010	–	−0.2026	–	–	0.4177	1.0500
Thailand	0.1987	–	0.0150	–	−0.2748	–	–	0.8619	0.9400
Fomer USSR	–	–	−0.0200	−0.2017	–	0.1844	–	–	–
Rest of the world	–	–	–	–	–	–	–	–	–

Note : "—" means "do not apply to the countries or regions."

Appendix B ; Baseline projections

Table B1. Exogenous variables

	Unit	Source	2001	2010(estimation)
World crude oil price	2001=1	World crude oil price in 2001 dollars per unit, reference case, U.S. department of energy	1.00	1.09
Domestic sugar price, EU15	1995=1	Intervention price for white sugar, OECD (2003)	632.0	632.0
Domestic sugar price, Japan	1,000 Yen/Tonnes	White sugar, refined, lower price, OECD (2003)	122.0	125.7
Producer price of wheat, U.S.	1990=1	OECD (2002)	1.29	1.26
Producer price of maize, U.S.	1990=100	World Food Model, FAO (2002)	80.80	74.70
Producer price of cereal, EU15	1990=1	OECD (2002)	1.35	1.32
Producer price of maize, China Mainland	2001=1	World Food Model, FAO (2002)	1.00	0.99

Table B2. Projected sugar prices

	Unit	Source	2001	2010(estimation)
World raw sugar price	USC/lb	International Sugar Organization	8.64	5.85
World white sugar price	US$/Tonnes	International Sugar Organization	248.90	173.00
Domestic sugar price, Brazil	Real, 50 kg/bag	Crystal sugar price, USP/ESALQ/CEPEA	23.60	18.18
Domestic sugar price, USA	USD/t	Raw sugar price, New York No.14, OECD (2003)	453.7	463.9
Domestic sugar price, India	1990=1	Non-centifugal sugar producer price, OECD (2003)	620.0	620.0

Table B3. Projected ethanol prices

	Unit	Source	2001	2010(estimation)
World ethanol price	2001=1	By authors' estimate	1.00	1.13
Domestic ethanol price, Brazil	R$/1,000 liters	Fuel anhydrous ethanol price, USP/ESALQ/CEPEA	626.24	532.06
Domestic ethanol price, EU15	1982=100	Ethanol producer price, U.S. department of energy	169.70	154.69
Domestic ethanol price, USA	1982=100	Ethanol producer price, U.S. department of energy	169.70	157.82
Domestic ethanol price, India	1990=1	Brazilian fuel ethanol price, USP/ESALQ/CEPEA	2.61	2.90

Table B4. Ethanol poduction

(thousand metric tonnes)

	1990	2001	2010 (estimation)	Growth rate 1990/2001	Growth rate 2001/2010
World	18, 581	20, 704	26, 607	0. 9%	2. 5%
Brazil	12, 028	11, 308	13, 194	−0. 5%	1. 6%
OECD countries total	3, 883	6, 126	9, 505	3. 9%	4. 5%
USA	2, 216	4, 574	7, 541	6. 2%	5. 1%
EU15	1, 144	1, 119	1, 474	−0. 2%	2. 8%
Mexico	126	128	134	0. 1%	0. 5%
Hungary	108	43	48	−7. 3%	1. 1%
Poland	230	160	186	−3. 0%	1. 5%
Turkey	39	39	49	0. 0%	2. 4%
New Zealand	7	15	16	6. 5%	1. 1%
Norway	13	17	19	2. 1%	1. 1%
Czech Republic	—	23	26	—	1. 5%
Slovakia	0	9	11	—	1. 1%
India	1, 175	2, 064	2, 490	4. 8%	1. 9%
China, Mainland	43	350	390	19. 2%	1. 1%
ACP countries	14	22	27	3. 7%	1. 9%
Thailand	77	83	90	0. 6%	0. 8%
Former USSR	191	346	406	5. 1%	1. 6%
Rest of the world	1, 170	405	505	−8. 5%	2. 2%

Source : FAOSTAT (1990, 2001), authors' estimates (2010).

Table B5. Ethanol consumption

(thousand metric tonnes)

	1990	2001	2010 (estimation)	Growth rate 1990/2001	Growth rate 2001/2010
World	18, 675	20, 740	26, 607	0. 9%	2. 5%
Brazil	12, 676	11, 146	12, 919	−1. 1%	1. 5%
OECD countries total	3, 675	7, 019	10, 610	5. 5%	4. 2%
USA	1, 974	4, 739	7, 900	7. 6%	5. 2%
EU15	814	1, 045	1, 218	2. 1%	1. 5%
Mexico	134	258	318	5. 6%	2. 1%
Japan	320	420	518	2. 3%	2. 1%
Korean Republic	69	163	198	7. 5%	1. 9%
Canada	1	76	89	43. 0%	1. 6%
Hungary	94	35	38	−8. 0%	1. 1%
Poland	190	158	184	−1. 5%	1. 5%
Switzerland	18	28	32	3. 9%	1. 3%
Turkey	44	37	47	−1. 4%	2. 5%
New Zealand	3	7	8	6. 4%	2. 0%
Norway	13	21	25	3. 9%	1. 5%
Czech Republic	—	15	16	—	0. 2%
Slovakia	—	16	18	—	1. 5%
India	1, 152	2, 031	2, 454	4. 8%	1. 9%
China, Mainland	22	105	122	13. 9%	1. 5%
ACP countries	18	50	62	8. 8%	2. 3%
Thailand	40	7	7	−13. 4%	0. 5%
Former USSR	61	289	331	13. 8%	1. 4%
Rest of the world	1, 031	93	99	−18. 2%	0. 7%

Source : FAOSTAT (1990, 2001), authors' estimates (2010).

Table B6. Ethanol export

(thousand metric tonnes)

	1990	2001	2010 (estimation)	Growth rate 1990/2001	Growth rate 2001/2010
World	2, 015	2, 322	2, 668	1. 2%	1. 4%
Brazil	30	256	351	19. 6%	3. 2%
OECD countries total	1, 562	1, 141	1, 243	−2. 6%	0. 9%
USA	648	443	355	−3. 1%	−2. 2%
EU15	719	612	789	−1. 3%	2. 6%
Mexico	0. 15	25	27	53. 4%	1. 0%
Japan	0. 07	0. 00	0. 00	—	—
Korean Republic	1	2	3	3. 6%	1. 3%
Canada	6	30	34	14. 1%	1. 3%
Hungary	142	9	10	−20. 7%	1. 4%
Poland	40	2	3	−22. 9%	4. 6%
Switzerland	0. 03	0. 04	0. 04	1. 0%	1. 0%
Turkey	0	2	2	—	0. 1%
New Zealand	4	9	9	7. 6%	0. 3%
Czech Republic	—	7	11	—	3. 8%
India	23	33	36	3. 0%	0. 9%
China, Mainland	21	245	268	22. 9%	0. 9%
ACP countries	0. 17	22	26	49. 8%	1. 9%
Thailand	37	79	88	6. 5%	1. 1%
Former USSR	130	78	88	−4. 2%	1. 2%
Rest of the world	213	470	569	6. 8%	1. 9%

Source : FAOSTAT (1990, 2001), authors' estimates (2010).

Table B7. Ethanol import

(thousand metric tonnes)

	1990	2001	2010 (estimation)	Growth rate 1990/2001	Growth rate 2001/2010
World	2, 108	2, 359	2, 668	0. 9%	1. 2%
Brazil	678	94	76	−15. 2%	−2. 1%
OECD countries total	1, 348	2, 033	2, 348	3. 5%	1. 4%
USA	406	608	714	3. 4%	1. 6%
EU15	389	538	533	2. 7%	−0. 1%
Mexico	8	155	211	27. 9%	3. 1%
Japan	320	420	518	2. 3%	2. 1%
Korean Republic	70	166	200	7. 4%	1. 9%
Canada	2	106	123	37. 6%	1. 5%
Hungary	129	0. 04	0. 04	−49. 4%	0. 6%
Poland	—	0. 03	0. 03	—	0. 7%
Switzerland	18	28	32	3. 9%	1. 3%
Turkey	5	0. 03	0. 03	−34. 3%	0. 7%
New Zealand	0. 05	1	1	29. 8%	0. 7%
Norway	0. 4	5	6	21. 9%	2. 7%
Czech Republic	—	0. 3	0. 3	—	0. 7%
Slovakia	—	6	8	—	2. 2%
India	0. 04	0. 30	0. 33	19. 6%	0. 9%
China, Mainland	0. 2	0. 5	0. 5	7. 7%	0. 7%
ACP countries	4	49	62	23. 1%	2. 3%
Thailand	0. 02	4	6	53. 8%	4. 8%
Former USSR	—	21	13	—	−4. 8%
Rest of the world	78	157	163	6. 0%	0. 4%

Source : FAOSTAT (1990, 2001), authors' estimates (2010).

Table B8. Sugar poduction

(raw sugar equivalent, million metric tonnes)

	1990	2001	2010 (estimation)	Growth rate 1990/2001	Growth rate 2001/2010
World	110.65	133.08	163.37	1.5%	2.1%
Brazil	7.94	20.40	26.15	6.6%	2.5%
OECD countries total	37.00	38.86	47.33	1.3%	2.0%
USA	6.34	7.58	8.75	1.8%	1.5%
EU15	17.98	15.78	18.76	0.1%	1.7%
Australia	3.68	4.16	5.33	3.3%	2.5%
Mexico	3.28	5.24	5.99	3.6%	1.4%
Japan	0.93	0.82	0.81	−2.1%	0.0%
Canada	0.14	0.10	0.15	−1.9%	4.9%
Hungary	0.56	0.44	0.58	−5.6%	2.8%
Poland	2.22	1.68	1.87	−0.1%	1.1%
Switzerland	0.16	0.16	0.22	2.6%	3.1%
Turkey	1.72	2.25	4.02	2.8%	6.0%
Czech Republic	—	0.49	0.60	—	1.9%
Slovakia	—	0.17	0.23	—	2.9%
India	11.76	20.48	22.26	4.6%	0.8%
China, Mainland	6.88	9.24	11.28	−0.2%	2.0%
Cuba	8.04	3.75	3.60	−5.5%	−0.4%
ACP countries	5.86	6.85	8.65	1.2%	2.4%
South Africa	2.03	2.50	3.31	2.5%	2.8%
Thailand	3.51	5.44	7.46	5.2%	3.2%
Fomer USSR	—	4.25	6.93	—	5.0%
Rest of the world	27.64	21.31	26.40	−2.3%	2.2%

Source : FAOSTAT (1990, 2001), authors' estimates (2010).

Table B9. Sugar consumption

(raw sugar equivalent, million metric tonnes)

Consumption (raw sugar equivalent, million metric tonnes)	1990	2001	2010 (estimation)	Growth rate 1990/2001	Growth rate 2001/2010
World	108.88	133.40	163.11	1.3%	2.0%
Brazil	6.95	9.62	12.24	2.7%	2.4%
OECD countries total	35.48	39.05	43.51	0.7%	1.1%
USA	7.90	9.37	10.36	1.4%	1.0%
EU15	12.92	14.37	15.10	0.7%	0.5%
Australia	0.94	0.92	1.17	−0.9%	2.4%
Mexico	4.34	4.48	5.19	0.2%	1.5%
Japan	2.78	2.33	2.43	−1.8%	0.4%
Korean Republic	0.81	1.05	1.35	1.5%	2.5%
Canada	1.04	1.13	1.33	0.1%	1.7%
Hungary	0.48	0.40	0.42	−1.2%	0.6%
Poland	1.87	1.70	1.83	−0.7%	0.7%
Switzerland	0.29	0.33	0.35	1.2%	0.5%
Turkey	1.75	1.97	2.85	0.8%	3.8%
New Zealand	0.17	0.23	0.29	2.2%	2.5%
Norway	0.17	0.19	0.20	0.9%	0.5%
Czech Republic	—	0.38	0.43	—	1.2%
Slovakia		0.20	0.22	—	0.9%
India	10.99	18.10	21.37	3.8%	1.7%
China, Mainland	7.95	10.19	12.76	−1.2%	2.3%
Cuba	0.70	0.71	0.81	0.3%	1.4%
ACP countries	4.54	7.92	9.81	3.8%	2.2%
South Africa	1.35	1.43	1.51	1.2%	0.5%
Thailand	1.06	1.92	2.90	4.7%	4.2%
Fomer USSR	—	11.41	15.26	—	3.0%
Rest of the world	39.87	33.06	42.93	−1.7%	2.6%

Source : FAOSTAT (1990, 2001), authors' estimates (2010).

Table B10. Sugar export

(raw sugar equivalent, million metric tonnes)

Export (raw sugar equivalent, million metric tonnes)	1990	2001	2010 (estimation)	Growth rate 1990/2001	Growth rate 2001/2010
World	30.58	44.68	51.30	2.7%	1.4%
Brazil	1.63	11.63	13.84	12.6%	1.8%
OECD countries total	11.90	15.32	17.82	2.6%	1.5%
USA	0.52	0.19	0.17	−9.6%	−0.7%
EU15	7.70	9.22	10.28	1.9%	1.1%
Australia	2.86	3.58	4.18	3.2%	1.6%
Mexico	0.01	0.27	0.94	35.4%	13.4%
Japan	0.01	0.00	0.00	−1.6%	−0.3%
Korean Republic	0.33	0.39	0.41	1.4%	0.5%
Canada	0.04	0.07	0.07	3.0%	0.4%
Hungary	0.01	0.01	0.18	6.7%	30.5%
Poland	0.39	0.34	0.13	1.8%	−9.2%
Switzerland	0.02	0.02	0.02	−0.7%	0.3%
Turkey	0.01	0.98	1.13	42.7%	1.4%
New Zealand	0.01	0.02	0.02	8.6%	−0.4%
Norway	0.00	0.00	0.00	5.4%	−0.9%
Czech Republic	—	0.19	0.25	—	2.8%
Slovakia	—	0.03	0.04	—	0.34%
India	0.03	1.55	0.92	23.9%	−5.1%
China, Mainland	0.64	0.29	0.38	−1.7%	2.9%
Cuba	7.17	2.94	2.79	−6.0%	−0.5%
ACP countries	2.79	2.84	3.14	1.7%	1.0%
South Africa	0.98	1.57	1.81	3.6%	1.5%
Thailand	2.43	3.38	4.54	4.8%	3.0%
Fomer USSR	0.00	0.59	0.56	—	−0.5%
Rest of the world	3.01	4.59	5.50	4.3%	1.8%

Source : FAOSTAT (1990, 2001), authors' estimates (2010).

Table B11. Sugar import

(raw sugar equivalent, million metric tonnes)

Import (raw sugar equivalent, million metric tonnes)	1990	2001	2010 (estimation)	Growth rate 1990/2001	Growth rate 2001/2010
World	29.65	41.75	51.30	1.9%	2.1%
Brazil	0.00	0.01	0.01	17.1%	1.2%
OECD countries total	13.19	12.12	14.06	−1.6%	1.5%
USA	1.91	1.52	1.78	−1.6%	1.6%
EU15	4.22	5.28	6.60	0.4%	2.2%
Australia	0.02	0.03	0.03	1.1%	2.5%
Mexico	1.93	0.09	0.09	−25.7%	0.4%
Japan	1.72	1.53	1.62	−0.7%	0.5%
Korean Republic	1.10	1.54	1.77	2.5%	1.4%
Canada	1.02	1.22	1.24	−1.0%	0.2%
Hungary	0.04	0.03	0.03	−6.8%	1.7%
Poland	0.04	0.09	0.11	6.9%	1.9%
Switzerland	0.12	0.20	0.15	4.5%	−2.8%
Turkey	0.71	0.00	0.00	−33.1%	1.6%
New Zealand	0.18	0.24	0.31	2.6%	2.7%
Norway	0.18	0.19	0.20	0.5%	0.5%
Czech Republic	—	0.08	0.09	—	1.1%
Slovakia	—	0.08	0.03	—	−11.0%
India	0.01	0.03	0.04	8.2%	1.6%
China, Mainland	1.16	1.24	1.90	−4.4%	4.4%
Cuba	0.00	0.00	0.00	—	—
ACP countries	1.51	3.82	4.33	5.9%	1.2%
South Africa	0.04	0.01	0.01	−4.0%	1.3%
Thailand	0.00	0.00	0.01	32.2%	2.6%
Fomer USSR	—	7.46	8.88	—	1.8%
Rest of the world	13.74	17.05	22.07	1.0%	2.6%

Source : FAOSTAT (1990, 2001), authors' estimates (2010).

Appendix C ; Major estimated equations

〈Ethanol markets〉

Per capita ethanol consumption in Brazil

$$PQCE_t = PQCE_{t-1} * ((DPE_t/DPE_{t-1})\hat{}\,-0.3707 * (I_t/I_{t-1})\hat{}\,0.2956) * 0.9580$$
$$(-2.5539) \qquad (0.6178)$$
$$R^2 = 0.9585,\ n = 11\ (\text{From 1990 to 2000})$$

Per capita ethanol consumption in USA

$$PQCE_t = PQCE_{t-1} * ((DPG_t/DPG_{t-1})\hat{}\,-0.4426) * 1.0490$$
$$(-1.0740)$$
$$R^2 = 0.5512,\ n = 18\ (\text{From 1983 to 2000})$$

Ethanol production in USA

$$QPE_t = QPE_{t-1} * ((DPE_t/DPE_{t-1})\hat{}\,0.6854 * (PPM_t/PPM_{t-1})\hat{}\,-0.2131) * 1.0610$$
$$(1.9687) \qquad (-0.7210)$$
$$R^2 = 0.9240,\ n = 13\ (\text{From 1988 to 2000})$$

Ethanol export in Brazil

$$EXE_t = EXE_{t-1} * ((WEP_t/WEP_{t-1})\hat{}\,0.3175 * (DPE_t/DPE_{t-1})\hat{}\,-0.7047) * 1.0180$$
$$(1.6774) \qquad (-3.4759)$$
$$R^2 = 0.4902,\ n = 10\ (\text{From 1991 to 2000})$$

Ethanol import in USA

$$IME_t = IME_{t-1} * ((MPE_t/MPE_{t-1})\hat{}\,-0.1459 * (DPE_t/DPE_{t-1})\hat{}\,0.3612) * 1.0230$$
$$(-1.7743) \qquad (3.7183)$$
$$R^2 = 0.8674,\ n = 9\ (\text{From 1992 to 2000})$$

〈Sugar markets〉

Sugarcane area harvested in Brazil

$$AHSC_t = AHSC_{t-1} * ((DPS_{t-1}/DPS_{t-2})\hat{}\,0.3259) * 1.0100$$
$$(1.7796)$$
$$R^2 = 0.2649,\ n = 9\ (\text{From 1992 to 2000})$$

Sugarcane area harvested in Thailand

$$AHSC_t = AHSC_{t-1} * ((PPSC_{t-1}/PPSC_{t-2})\hat{}\,0.3257) * 1.0150$$
$$(1.8646)$$
$$R^2 = 0.8773,\ n = 14\ (\text{From 1987 to 2000})$$

Sugar beet area harvested in EU15

$$AHSB_t = AHSB_{t-1} * ((DPS_{t-1}/DPS_{t-2})\hat{}\,0.2711 * (PPC_{t-1}/PPC_{t-2})\hat{}\,-0.1667) * 1.0052$$
$$(1.9264) \qquad (-0.4677)$$
$$R^2 = 0.6824,\ n = 8\ (\text{From 1993 to 2000})$$

Sugar beet area harvested in USA

$$AHSB_t = AHSB_{t-1} * ((DPS_{t-1}/DPS_{t-2})\hat{}\,0.2092 * (PPM_{t-1}/PPM_{t-2})\hat{}\,-0.1173 *$$
$$(2.9309) \qquad (-0.4863)$$
$$(PP_{w,t-1}/PP_{w,t-2})\hat{}\,-0.0121) * 1.0010$$
$$(-0.4447)$$
$$R^2 = 0.6816,\ n = 16\ (\text{From 1985 to 2000})$$

Per capita sugar consumption in Brazil

$$PQCS_t = PQCS_{t-1} * ((DPS_t/DPS_{t-1})\hat{}\,-0.2443 * (I_t/I_{t-1})\hat{}\,0.2513) * 1.0010$$
$$(-0.5910) \qquad (1.4001)$$
$$R^2 = 0.6952,\ n = 19\ (\text{From 1982 to 2000})$$

Per capita sugar consumption in EU15

$$PQCS_t = PQCS_{t-1} * ((I_t/I_{t-1})\hat{}\,0.2478 * (DPS_t/DPS_{t-1})\hat{}\,-0.2932) * 0.9990$$
$$(1.3386) \qquad (2.2454)$$
$$R^2 = 0.8223,\ n = 23\ (\text{From 1978 to 2000})$$

Per capita sugar consumption in USA

$$PQCS_t = PQCS_{t-1} * ((I_t/I_{t-1})\hat{}\,0.1620 * (DPS_t/DPS_{t-1})\hat{}\,-0.3470) * 1.0025$$
$$(0.4921) \qquad (-2.0164)$$
$$R^2 = 0.6875,\ n = 15\ (\text{From 1986 to 2000})$$

Sugar export in Brazil

$$EXS_t = EXS_{t-1} * ((WRP_t/WRP_{t-1})\hat{}\,0.3718 * (DPS_t/DPS_{t-1})\hat{}\,-0.7080) * 1.0150$$
$$(0.9964) \qquad (-1.7959)$$
$$R^2 = 0.8473,\ n = 9\ (\text{From 1992 to 2000})$$

Preferential import for ACP countries in EU15

$$IMS1_t = IMS1_{t-1} * ((WRP_t/WRP_{t-1})\hat{}\,-0.23322 * (DPS_t/DPS_{t-1})\hat{}\,0.12867) * 1.0360$$
$$(-0.1421) \qquad (0.4046)$$
$$R^2 = 0.2950,\ n = 7\ (\text{From 1994 to 2000})$$

Other imports program in EU15

$$IMS2_t = IMS2_{t-1} * ((WRP_t/WRP_{t-1})\hat{}\,-0.6057 * 1.0120$$
$$(-0.2523)$$
$$R^2 = 0.9062,\ n = 6\ (\text{From 1995 to 2000})$$

Sugar import in Japan

$$IMS_t = IMS_{t-1} * ((DPS_t/DPS_{t-1})\hat{}\,0.4972) * 1.0210$$
$$(1.6951)$$
$$R^2 = 0.5092,\ n = 11\ (\text{From 1990 to 2000})$$

Notes :1) The symbol of "^" means power. 2) The figures under each elasticity are *t*-value.