HOW DO BRAZIL'S MANDATED BLENDING REQUIREMENT AND WORLD CRUDE OIL PRICE AFFECT INTERNATIONAL ETHANOL MARKETS

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YULIN ZHAO

Dr. Julian Binfield, Thesis Supervisor

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The undersigned, appointed by the dean of the Graduate School, have examined the entitled

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Presented by Yulin Zhao,

A candidate for the degree of the degree of Master of Science

And hereby certify that, in their opinion, it is worthy of acceptance.

Professor Julian Binfield

Professor Wyatt Thompson

Professor Fabio Chaddad

Professor Vitor Trindade

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TABLE OF CONTENTS

ACKNOWLEDEMENTS ii

List of tables v

Abstract viii

Chapter1 Introduction 1

1.1 History of Brazil's Ethanol Industry 1

1.2 The Objectives of This Study 4

Chapter 2 Literature Review 5

2.1 Studies Investigating the Impacts of Biofuel Policies 5

2.2 Studies Regarding Other Aspects of Biofuel Markets 10

2.3 Methodology Selections 11

Chapter 3 A Short Discussion of Important Variables 20

3.1 Discussion of Prices 20

3.2 Discussion of Ethanol Production and Consumption 23

Chapter 4 Brazil's ethanol and sugar model structure, estimation and simulation 27

4.1 Data Source 27

4.2 Model Structure, Estimation and Simulation 28

4.3 Ethanol Sector 32

4.3.1 Ethanol Demand 32

4.3.2 Ethanol Supply 35

4.3.3 Inventory Demand and Net Export 36

4.4 Sugar sector 36

4.4.1 Sugar Demand 36

4.4.2 Sugar Supply 37

4.5 Model Closure 39

4.6 Scenarios 41

Chapter 5 Scenarios Results 43

5.1 Shock: blending ratio rises to 30% 43

5.1.1 Model one: close the model of Brazil and the rest of the world 43

5.1.2 Model two: close the model of Brazil, U.S., EU and the rest of the world 48

5.2 Shock: world crude oil price increases by 20% 53

5.2.1 Model one: close the model of Brazil and the rest of the world 53

5.2.2 Model two: close the model of Brazil, US, EU and the rest of the world 57

Chapter 6 Conclusion 64

Bibliography 68

Appendix 71

A Data names, units, and sources 71

B Tables showing the baselines of two models 73

C Tables showing the absolute values of scenarios results 75

LIST OF CHARTS

Chart Page

Chart 3.1 Important Prices for the Sector 20
Chart 3.2 Comparison of gasoline C price and pump hydrous ethanol price 22
Chart 3.3 Total ethanol production, anhydrous ethanol production and hydrous ethanol production of Brazil 23
Chart 3.4 Hydrous ethanol use and gasoline use in Brazil 24
Chart 3.5 Monthly data for gasoline C consumption and hydrous ethanol consumption 25
Chart 3.6 Accumulation number of Brazil’s various car fleets 25
Chart 3.7 Brazil’s ethanol vehicles and flex-fuel vehicles number for each year 26
Chart 5.1 Price ratios for baseline and the first scenario 46
Chart 5.2 Absolute values of key variables changes resulted from world crude oil price shock .. 55

LIST OF FIGURES

Figure Page

Figure 4.1 Ethanol flow chart 29

LIST OF TABLES

Table Page

Table 5.1 Scenario result for model one shock one: setting mandate blending ratio to 30% 44
Table 5.2 Scenario result of Brazil for model two shock one: setting mandate blending ratio to 30%.. 49
Table 5.3 Scenario result of U.S. for model two shock one: setting mandate blending ratio to 30%.. 51
Table 5.4 Scenario result of EU for model two shock one: setting mandate blending ratio to 30% 51
Table 5.5 Scenario result for model one shock two: a 20% rise in world crude oil price 54
Table 5.6 Scenario result for model two shock two: a 20% rise in world crude oil price 59
Table 5.7 Scenario result of U.S. for model two shock two: world crude oil price increases by 20%.. 61
Table 5.8 Scenario result of EU for model two shock two: world crude oil price increases by 20% 61

HOW DO BRAZIL'S MANDATED BLENDING REQIREMENT AND WORLD CRUDE OIL PRICE AFFECT INTERNATIONAL ETHANOL MARKETS?

Dr. Julian Binfield, Thesis Supervisor

ABSTRACT

In recent years, more and more countries and areas have become increasingly concerned with environmental problems, and energy independence goals as a result of the high crude oil price. In this context, biofuels are widely recognized as an important means of lowering the carbon emissions of transport, and utilizing alternative energy sources, which are beneficial to increasing energy security. Consequently, a great number of national governments across the world have made legislation to require biofuels to form a proportion of transport fuel use. Brazil is one of such countries. It is the second largest country in terms of biofuel production. Also, its biofuels exports and imports have remarkable impacts on international markets. This study examines, in particular, the impacts of Brazil's mandate blending ratio of biofuel in pure gasoline, and a rise in world crude oil price on international ethanol markets. A structure model of Brazil's sugar and ethanol markets is developed and estimated based on regressions and modeler's judgments. This study uses two ways to close the model. The first one is to use single equations for demand from the rest of world. The other way is to link Brazil's markets to FAPRI's models of U.S., EU, and world markets. A baseline projection for the period marketing year 2011/2012 to 2020/2021 is determined. Then, two shocks of the mandated blending ratio and world crude oil are applied. The first scenario indicates

blending requirement boosts anhydrous ethanol price, gasoline C price and international hydrous ethanol price. Also, there is a rise in Brazil's consumption of anhydrous ethanol and gasoline C. For the second model, the direction of change for all the endogenous variables are consistent with those in model one, but the magnitude differs. An increase in world crude oil price gives rise to a large switch from petroleum products to biofuels.

Chapter1 Introduction

Recent years have seen an increase in the number of studies that focus on the relationship between agricultural markets and energy markets. As countries such as U.S. and Brazil have become increasingly concerned with environmental problems and a desire to achieve energy independence, they have begun to pay more attention on renewable sources of energy, and have put a great deal of investment in green industries, including biofuel. Brazil is the second largest country in terms of biofuel production, and its exports and imports have significant impacts on international market.

1.1 History of Brazil's Ethanol Industry

Due to the Arab oil embargo the cost of oil imports of Brazil, which was strongly dependent on imported oil at the time, rose dramatically in late 1973. World sugar prices declined sharply at the same time. Under such conditions, the Brazil's government lunched the National Ethanol Programme (ProAlcool) in the late 1975, with the purpose of reducing the need for oil imports, providing a new developing opportunity for Brazilian sugar industry and creating the conditions for the development of the ethanol industry. The first step was to promote the production of anhydrous [1]ethanol blending into gasoline and to provide incentives for the development of ethanol vehicles which were fuelled exclusively with hydrous ethanol. Thus, the boom

[1] Anhydrous ethanol does not contain any water. It is generated by putting hydrous ethanol through a dehydration process after distillation to remove the remaining water. It is used as additives in gasoline. Hydrous ethanol is the ethanol containing water, and can be used directly in engines of ethanol-fuelled vehicles and flexible-fuel vehicles.

time of Brazilian ethanol industry was the early 1970's, and ethanol production increased more than 500%.

Following the second major oil crisis in 1979 the second stage of the progamme was implemented which was more ambitious and comprehensive. A series of tax and financial incentives was introduced to encourage production and the use of purely ethanol-fuelled vehicles and to the ethanol production as well. With the strong response, the Brazilian ethanol programme flourished in the early 1980's. Ethanol production in 1985 was more than triple that of 1979 and ethanol made up about half of Brazil's liquid fuel supply (FAO, 2008; Sandalow, 2006).

The world oil price fell sharply in 1986. Meanwhile, as Brazil was confronted by the serious inflation problems, subsidies to the ethanol industry were cut back drastically. Consequently, the advantage that ethanol prices had over gasoline prices was eliminated. Additionally, the increase in world sugar prices made exports of refined sugar more profitable, which resulted in a shortage of ethanol. But these changes did not affect automakers immediately, and they continued to manufacture a great amount of ethanol-only cars (FAO, 2008; Sandalow, 2006).

During the 1990's, the government’s economic incentives were dismantled. In particular, the Sugar and Ethanol institute, which had regulated the Brazilian sugar and ethanol industry for a long time, was eliminated. With the deregulation and privatizations, there were little political supports to the ethanol industry, resulting in rapidly diminishing use of ethanol. However, the national government continued the requirement of the mixture of anhydrous ethanol with gasoline (FAO, 2008; Sandalow, 2006).

Most recently, the liberalization of prices in the industry and the high oil prices in the world market led to the revitalization of ethanol fuel and increasing ethanol exports. Also, the explosive growth of flex-fuel vehicles, which were capable of running on gasoline, ethanol or any combination of the two fuels has been a crucial factor in domestic market development. Relative to the 1970s and 1980s the Brazilian sugar and ethanol industry now depends much more on market mechanisms. There is no direct restriction or incentive on the ethanol industry. The only tools that are left are mandatory blending of anhydrous ethanol into gasoline, the tax differentials on fuels and the sales tax differentials on automobiles running on ethanol (FAO, 2008; Tokgoz & Elobeid, 2007). However the government still plays a central role in the industry through gasoline prices that are set by Petrobas.

The Brazilian government has kept a lid on price of gasoline and diesel through Petrobras. Since the fuels have a large weighting in Brazil's consumer price index, in order to control inflation, the government has prevented Petrobras from passing on rises in crude oil to consumers. When Petrobras raises wholesale gasoline and diesel prices, government offsets the increase at the pump through tax cuts.

Because of its lower fuel efficiency, hydrous ethanol is considered at price parity with gasoline when its pump price is 70% that of gasoline. Thus, holding gasoline prices steady at the pump irrespective of international oil prices essentially has a direct impact on ethanol, namely creating a ceiling for ethanol prices. Given the number of flex-fuel vehicles, it is hard for the ethanol price to break the 70% barrier. Once ethanol price is above 70% of petroleum price, consumers prefer to use gasoline rather than ethanol. Then, producers are discouraged to produce ethanol(OPIS, 2012).

1.2 The Objectives of This Study

This study begins with an analysis of the recent biofuel boom in Brazil, using the historical period from 2000-2010 for the purpose of model estimation. It also uses stimulation to establish a benchmark for the biofuel economy, from which the impact of future mandates and fluctuation of world crude oil are conducted.

The objectives of this study are:

i) Develop a model of Brazil's sugar and ethanol markets and discuss how the mandate blending ratio and world crude oil price affect gasoline C price, domestic and international ethanol price, and the world sugar market.

ii) Link Brazil's ethanol model to EU model and U.S. model, and then compare the results with those in the first model to determine the importance of interaction with international markets.

Chapter 2 Literature Review

Given the rising interest in biofuels production and consumption and the changing landscape of the fuel markets, more researchers and international organizations have studied the ethanol market, its linkage with agricultural markets as well as other energy markets. Traditional regressions and time series models have been used to do analysis as well as both partial equilibrium models and general equilibrium models. Each of them has their advantages and emphasis.

2.1 Studies Investigating the Impacts of Biofuel Policies

The development of biofuel industry is influenced deeply by a wide range of policies provided at different points in the biofuel supply chain. Those supports include inputs supports, agricultural production supports, processing and marketing supports and supports to consumption. Those biofuel policies are in rapid evolution.

Recently, most research focuses on the effects of policies on processing, marketing and consumption sections. Support policies related to processing and marketing section involve tax credits, incentives and exemptions, mandates use requirements, trade policies and subsidies for capital investment. Supports to consumption include subsidies for purchase of biofuels and co-products, tax exemptions and subsidies for flex-fuel vehicle purchase (FAO, 2008). Policies of blending mandates play a driving role in the development and growth of modern biofuel industries. Althoff, Ehmke, and Gray (2003) did a basic analysis on the effects of biodiesel mandatory blending. They thought that mandated requirement of a minimum amount of biodiesel blended into diesel fuel can affect the supply curves within the distillate fuel market, introducing additional costs for each gallon of fuel supplied to consumers. Because of the incremental cost added to each gallon of fuel, the supply curve will shift to left, leading to less fuel demanded at the new price. Then, this will motivate consumers search out alternative energy sources in the long run.

Schmitz, Schmitz, and Seale (2003) discussed effects of changing mandate blending ratio in more detail, focusing the economic welfare implications. They concluded that Brazilian sugarcane producers receive indirect subsidies through Brazil's biofuel policies, which means that sugarcane producers of Brazil and rest of the world sugarcane producers benefit from the increase in domestic sugarcane price which results from the increase in the blending ratio, if Brazilian sugarcane producers are risk neutral. Moreover, if Brazilian sugarcane producers are risk averse, they get larger subsidies than those who are risk neutral.

Koizumi (2003); Koizumi and Yanagishima (2005) analyzed the impact of an eight percent anhydrous ethanol blend ratio to domestic diesel oil using a world ethanol-sugar market projection model to discuss how this policy affect domestic ethanol and sugar markets and world markets. They drew the conclusion that this policy tool will be beneficial to expanding domestic ethanol markets and reducing oil imports. The world sugar price and ethanol price are expected to increase as a result of this Brazilian energy programme. These effects will persist for years, although the magnitudes of world sugar and ethanol price change are moderate.

Tariffs on biofuels are intended to protect domestic agriculture and biofuel industries, working as the support for domestic prices of biofuels and provide an incentive for domestic production. Recently, most research focus on the impacts of removing trade distortions. Martinez-Gonzalez, Sheldon, and Thompson (2007) assess the impact of elimination of trade distortions through an ethanol export supply function for Brazil and an ethanol import demand function for the United States. The study finds that there is a negative effect on Brazilian ethanol exports to U.S. if the price of sugar increases due to the substitution effects between sugar and ethanol production at the firms' plants. Similarly, an increase in oil prices has a negative effect on Brazilian ethanol export supply, as a result of a substitution effect in Brazil between oil and ethanol. Also, this research shows a positive effect on the ethanol price when corn price goes up and a positive effect on the ethanol price when the price of gasoline rises.

In addition to the evaluations of the effects of the single policy, most studies discuss the interaction impacts of the combination of those policies. As well as looking at mandatory blending requirement and import tariffs, many researchers are interested in the tax credit, which is used as a means for simulating demand for biofuel and make contributions to its competitive price comparing that of other energy sources and commercial viability. Elobeid and Tokgoz (2008) used a multimarket international ethanol model and analyzed the impact of removing the distortions in the U.S. ethanol market. The authors set two scenarios one of which is the removal of the trade distortions in the United States and the second one is removing the trade barriers and the federal tax credit for refiners that blend ethanol with gasoline. The study finds that trade barriers have been effective in protecting the domestic ethanol industry. With removal of trade distortion, the world ethanol price rises. Due to the comparative advantage of low cost ethanol production, Brazil will export more ethanol directly to the U.S.. Moreover, removing trade distortions will have effects on the corn market, by-products, and sugar market as well. As for the second scenario, the refiners will reduce their demand for ethanol.

De Gorter and Just (2007a) (2009) evaluate the economic effects of the biofuel mandate and excise-tax credits in the United States, and their interaction effects when they operate simultaneously. The study showed that mandate has an ambiguous effect on the consumer fuel price. It may increase or decrease consumer fuel price, depending on relative supply elasticities. Also, ethanol tax credit does not achieve its purpose of reducing oil consumption. The tax credit alone acts as a consumption subsidy for biofuels, but due to the mandated blending, the tax credit becomes an indirect gasoline consumption subsidy.

In the other research, they added import tariffs into the discussion, evaluating the economic effects of the import tariff with biofuel mandates and tax credit and without biofuel mandates or tax credit in the United States. When the tax credit alone is considered, the study indicates exporters like Brazil gain benefits from it. Eliminating the tariff with tax credits also brings benefits to exporters, but eliminating the tax credit reduces their initial profits. Authors additionally found that elimination of the tariff with a mandate causes the increase of domestic ethanol price(De Gorter & Just, 2007b). Similar to others' studies, Bowser, Khanna, and Onal (2010) discussed how long-run Renewable Fuel Standard(RFS) targets along with the Volumetric Ethanol Excise Tax Credit (VEETC) affect the domestic use of ethanol and how trade policies protect their domestic ethanol industry and distort the international biofuel market, applying the spatial partial equilibrium model. What is different from the studies mentioned above is that they also analyzed the effects on crop land uses in Brazil from the increased demand for sugarcane ethanol. They provided the evidence that livestock intensification may release the land required to increase sugarcane production. In fact, most research analyzing land use change choose to use a general equilibrium framework. For instance, Banse, Van Meijl, Tabeau, and Woltjer (2008) discusses the impact of EU Directive on the Promotion of Use of Biofuels and Progress Report on Biofuels of the European Commission on production, land use and trade.

Besides the national level incentives to ethanol industry, Cotti and Skidmore (2010) examined how state government subsidies and tax credit influence ethanol production capacity. They found that state-level per gallon tax credits and per gallon production subsidies primarily impact on ethanol plant location patterns, whereas federal mandates and subsidies drive the national production capacity.

2.2 Studies Regarding Other Aspects of Biofuel Markets

Tokgoz and Elobeid (2007) analyzed how price shocks of gasoline, corn and sugar affect ethanol and related agricultural markets in the U.S. and Brazil, using their partial equilibrium model. The study found that an increase in gasoline prices has different impacts on the U.S. and Brazilian ethanol markets. In the U.S., the total consumption of ethanol declines with the decrease of total composite gasoline consumption, though the share of ethanol in composite gasoline consumption rises. However, the rise in gasoline price results in an increase in total ethanol consumption in Brazil, because their vehicles run on up to 25% blended gasoline and the share of FFV is increasing drastically.

An increase in the U.S. corn price results in a reduction in ethanol production in the U.S., and makes importing of ethanol from Brazil become attractive. The increase in the world raw sugar price causes a greater percentage of sugarcane used in sugar production and finally ethanol and sugar prices tend to move together in Brazil. Using a multi-country, multi-sector, recursive dynamic, global computable general equilibrium model, Timilsina and Shrestha (2011) discussed how the rise in oil price affects the penetration of biofuels in the transportation fuel mix, agricultural outputs, land-use change and food supply.

Rajcaniova, Drabik, and Ciaian (2011) paid particular attention to how biofuel policies determine the biofuel prices and analyze which countries play a leading role in price determination in the international biofuel market. They drew the conclusion that, fossil fuel determines biofuel price in the price leading country, if the tax credit drives biofuel prices. However, if the blending mandate determines biofuel prices, biofuel prices are not likely to follow the pattern of fossil fuel markets. They determine that with regard to leadership in world biofuel market, U.S. and Brazilian ethanol policies both determine ethanol prices in other countries, and EU is the price leader in the international biodiesel market.

Gallagher, Schamel, Shapouri, and Brubaker (2006) analyzed the competitiveness of the U.S. corn ethanol industry, comparing it with Brazil's sugarcane ethanol. They built an international ethanol trade model and used an indicator for measuring the competitiveness of the U.S. industry. Finally, they concluded that with the removal of trade barriers in the ethanol market, the economic effects of corn ethanol and sugarcane ethanol will be equal and neither of them tends to have cost advantage. However, they may have advantage with seasonal patterns, according to corresponding cycles in corn prices, sugar prices, or foreign currency prices.

2.3 Methodology Selections

There are two main approaches in the applied in the analysis of effects of the biofuels boom: partial equilibrium modeling and computable general equilibrium modeling.

The computable general equilibrium model is a kind of macroeconomic model, of which all markets are explicitly represented and in equilibrium. It can simulate market economic behavior and provide a useful perspective on how external shocks affect the whole system (Virginie, 2009). It consists of several steps. The first one is building a Social Accounting Matrix (SAM), which is a balanced matrix, representing all economic transactions between different agents of the economy in a given period (Kretschmer & Peterson, 2010). Then, in order to represent the relationship between variables, it is necessary to specify an equation system, which contains macro-balancing equations, functional forms and behavior equations. Also, the model builders can use their own econometric research to calculate parameters or set parameters of behavioral equations according to others' related econometric research. Moreover, they need parameters that can in principle be derived using methods other than just econometrics. Finally, some model builders prefer to calibrate the parameters, examining whether the model is in accord with reality. If it is appropriate, the benchmark equilibrium is obtained (Virginie, 2009).

The Global Trade Analysis Project (GTAP) (Hertel, 1999) Model, a kind of computable general equilibrium model, is universally used for global economy analysis, since it is well-documented, publicly accessible and easily modified (Golub, Hertel, Taheripour, & Tyner, 2010), but GTAP data and GTAP model is often changed in some way. Also, GTAP data are sometimes used as an input in GE models. However, the standard GTAP does not contain a biofuel sector.

GTAP-BIO is designed for energy-economy-environment-trade linkages analysis.Taheripour, Birur, Hertel, and Tyner (2007) first disaggregated bioenergy sectors from the SAM, introducing three sectors, grains based ethanol, sugarcane based ethanol and biodiesel production from vegetable oil, into the standard GTAP database to support modeling framework. Taheripour and Tyner (2008), Taheripour, Hertel, and

Tyner (2011) made further modification of GTAP-BIO by adding byproducts of ethanol production and biodiesel production, since a distinct feature of the biofuel sector is that they can generate by-products as well as the main products. The standard GTAP framework does not permit multi-product sectors, so Taheripour, Hertel, Tyner, Beckman, and Birur (2010) modified the model to deal with joint production. Similarly,Bryant and Campiche (2009) calibrated and incorporated new production sectors, including feedstock production and production of biofuels themselves, into GTAP model. Also, the original petroleum and coal products sector is modified to reflect the incorporation of biofuels into the energy product and utilization processes.

Several distinguishing features make GTAP-BIO for the analysis of trade situations, byproducts, land cover change resulted from raise in biofuel feedstock productions, and the crop yield response caused by prices and policies. Firstly, after adding byproducts production and depicting its structure of nested demand for feed in livestock industry, it is more readily to discuss interactions between livestock sectors and biofuels, and other effects resulted from byproducts. Both livestock and biofuel industries compete for crop feedstock, so expansion of biofuel production results in higher crop price, thereby increasing the input costs for the livestock industry. Moreover, biofuel production is an incentive to conversion of pasture land to crops, which further raises production costs for ruminant(Bryant & Campiche, 2009).

However, some co-products, generated during the process of transforming the energetic crops into biofuels, such as cakes and glycerin from rapeseed and Distiller's

Dried Grains with Solubles (DDGS) from generated from the production process of grain based ethanol, can be used as animal feeds instead of higher price crops, which helps to reduce the cost of livestock industry. When biofuel production is encouraged, the joint production process in the biofuel industry indicates that byproducts increase as well, which leads to the reduction of their prices, making their prices lower relative to other animal feed ingredients. Thus, livestock producers have an incentive to use more byproducts in feedstuff instead of crops (Golub et al., 2010). For instance, breeders may replace their cattle food sources by co-products, thereby reducing the imports of soybeans (Virginie, 2009). In addition to its effects on the trade of related agricultural products, the fact that by-products can be used as animal feed is likely to change the land use effects. Even though more land may be used to produce energy crop, the demand for land by livestock feedstock may decline due to the availability of by-products (Kretschmer & Peterson, 2010).

Second, with respect of trade in GTAP model, there are two different views on bilateral trade. Under the Armington approach, GTAP model introduces a strong element of economic geography into the analysis, thereby differentiating products by national origin. In the GTAP trade specification, agents first make the decision on the sourcing of their imports and then, based on the resulting composite import price, they decide the optimal mix of imported and domestic goods. The main alternative to the Armingtion assumption is that of Integrated World Markets whose hypothesis is a single global market for agricultural commodities and a single market clearing price (Golub et al., 2010). Villoria and Hertel (2011)formulate an econometric model to evaluate which trade specification is more appropriate to the biofuel scenario. Ultimately, they prefer to the Armington model.

Third,Lee, Hertel, Sohngen, and Ramankutty (2005) introduced Agro-Ecological Zones (AEZs) to indicate the heterogeneity of land. Later, based on the evidence that land cannot move freely between alternative uses, scholars use the parameter of Constant Elasticity of Transformation (CET) to represent the ease of land mobility.

Hertel and Tsigas (1988) used a CET framework in a CGE model to represent the input factor land in detail. Banse et al. (2008) made this CET structure more complex by nesting several levels. He used a three-level CET nesting structure to differentiate different land use transformability across types of land use. This augmentation of model is favorable for depicting the competition for land between food and fuel.

Using this land use component in the model, some studies discuss the direct land use change, which occurs when a new activity occurs on the area of land (Young, 2011) . For instance, increased corn production is likely to cause the land conversion from corn-soybean rotation to continuous corn production. Apart from direct land use change, another research topic is indirect land use change (iLUC), which occurs as an unintended consequence of land use decisions (Young, 2011). For example, how the global indirect land use changes induced by expanded biofuel production affects the global greenhouse gas (GHG) emission (Golub et al., 2010). Since, iLUC component requires estimation with a global economic model which links global production, consumption and trade and energy, biofuel and agricultural markets within and across regions, GTAP model with land use component is appropriate.

Additionally, some studies discuss the yield changes resulted from the expansion of biofuel. There are two categories of yield changes: intensive one and extensive one. Yield intensification means higher yields on existing land in response to higher prices. With the increase in feedstock price as well as inelastic land supply, producers have an incentive to raise the use of non land inputs, such as fertilizer, pesticides, and some other purchased inputs to boost production per unit of land. In contrast, yield extensification, indicating lower yields on new lands in response to cropland expansion, happens when land which is used in pastures, forest, or other crops, is converted to grow feedstock. Due to the limitation of data, the same long run elasticity of yield is adopted for all crops and all regions in current applications of GTAP-BIO model. Also, with respect to the impact of expanding cropland into pasture and possible forest lands on average crop yield, researchers make the assumption that three additional acres of marginal cropland can offset the effect of diverting two hectares of current cropland to biofuel production (Golub et al., 2010).

One of the drawbacks of the GTAP system is that most of the parameters of the functional forms and behavioral equations are quantified in the light of econometric literature, not estimated by standard econometric methods. If these parameters are unavailable, they will be chosen by model builders. Up to now, there is a large part of model specification, data adjustment and parameter selection that remains unexplained in published models (Virginie, 2009). Therefore, in many cases the trustworthiness of a model may be based in the affirmation of the modeler (Valenzuela, Hertel, Keeney, & Reimer, 2007).

A computable general equilibrium model can provide a comprehensive picture of a whole economy. However, in most of time, it is aggregated, making it hard to capture what happens at the microeconomic level (Virginie, 2009). If the study needs to simulate policy proposals in detail, often a partial equilibrium model is a better choice.

With a partial equilibrium model the focus is on particular markets or sectors, examining these sectors or commodities as a closed system in the economy and ignoring interrelationships with other sectors or the macro-economy. Partial equilibrium models have a number of advantages. One of them is that it is beneficial to concentrating on a small number of variables and relationships among selected sectors. Partial equilibrium models are good at capturing supply and demand interrelationships among agricultural products, providing more details, especially more precise representation of policies.

Here I will focus on two examples of the application of partial equilibrium models for biofuels analysis: the FAPRI model and the Aglink-Cosimo model. The FAPRI/CARD International ethanol model is a non-spatial, multi-market world model consisting of many countries or regions. It contains a Rest-of-World aggregate (ROW) as well to close the model. The behavioral equations for the structure of the country include ethanol production, consumption, ending stocks and net trade. They have complete country models for U.S., Brazil and the EU27, Canada, China and India, but only net trade equations for other countries or regions due to the limitation of data available (FAPRI & CARD).

As for U.S. ethanol model, the total ethanol demand is divided into two parts: fuel ethanol and a residual demand for non-fuel consumption, such as industrial use and beverages use. Fuel ethanol is deduced from the cost function of blended gasoline production. They include U.S. ethanol price, crude oil price and gasoline supply in the function and introduce related biofuel policies measuring their effects on ethanol demand as the additive in gasoline. Blending gasoline demand is affected by gasoline price, ethanol price, biofuel policies, as well as population and income growth. The FAPRI authors derive the domestic ethanol production from the restricted profit function for producers. They maximize the profit subjected to capacity constraints (Witzke et al., 2008).

Organization for Economic Co-operation and Development (OECD) Secretariat and Member Countries developed and apply the Aglink model, which is a dynamic partial equilibrium model for agricultural product market. The Aglink model is sometimes simulated in conjunction with the FAO's Commodity Simulation Model (Cosimo), which covers a large set of developing countries. Aglink model, including all OECD countries and 36 countries and regions outside OECD, pays special attention to domestic and trade policies. It represents related policies in detail. When Aglink -Cosimo model is used to do simulations, the Aglink Sugar Model, which is the model to represent regional and international markets for sugarcane, sugar beets and raw and white sugar, is run separately sequentially. These two models are used simultaneously to analyze biofuel markets.

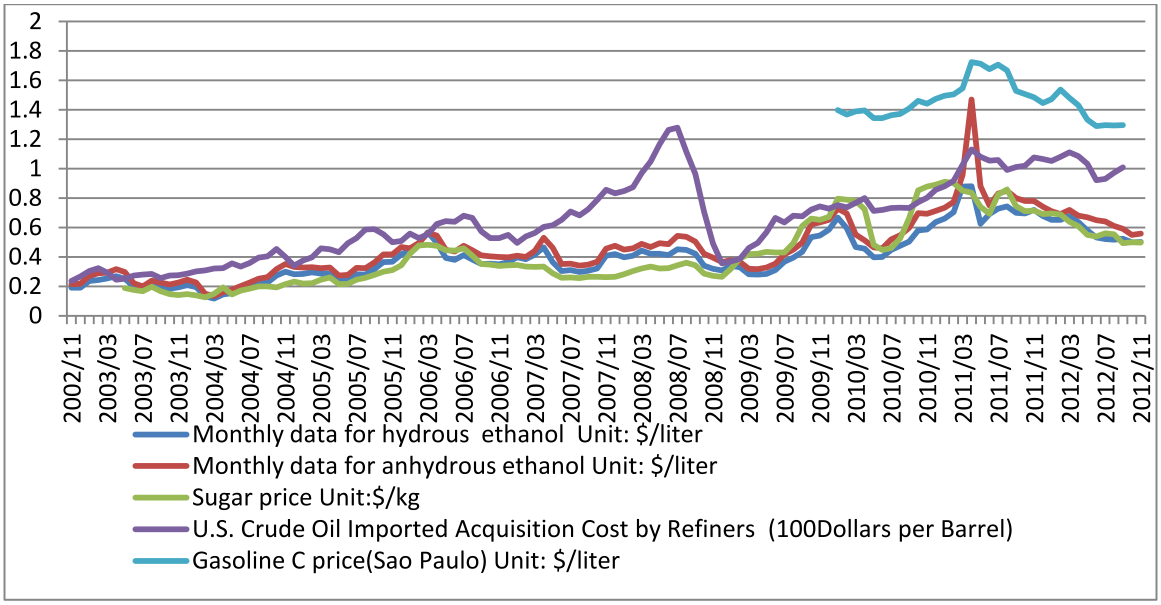
Biofuel modules in Aglink-Cosimo model capture the whole biofuel chains completely, containing both bioethanol and biodiesel. The production functions of bioethanol and biodiesel are in the double-log form. The independent variables are time, cost ratio between biofuel and petroleum-based fuel and impacts of policies. The shares of different feedstocks producing a certain biofuel are set based on the assumption of constant elasticities and driven by relative net production costs. Due to the lack of empirical data, the fact that information of biofuel production processes are obtained from one country makes that many parameters applied in the model are equal across countries. Some critics conclude that the biofuel production represented by Aglink model is therefore inappropriately applied widely (Witzke et al., 2008).

As a result of my particular research problems, I prefer to use a partial equilibrium model that allows one to study equilibrium, efficiency and comparative statics. It tends to be more transparent than many general equilibrium approaches and does not require extremely large database. Moreover, it facilitates the analysis of the specific policy at a very disaggregated level. For given policy problems, the flexibility that a partial equilibrium framework offers is preferable, particularly for the scope of the research project undertaken here.

Chapter 3 A Short Discussion of Important Variables

3.1 Discussion of Prices

Chart 3.1 Important Prices for the Sector



Prices of hydrous ethanol and anhydrous ethanol here are presented in Chart 3.1 and are the prices to producers, from the Center for Advanced Studies on Applied Economics (CEPEA). Data of gasoline C price comes from Brazilian Sugar Industry Association (UNICA), and US crude oil price is obtained from U.S. Energy Information Administration (EIA)[2].

It is quite clear that the price of hydrous ethanol and anhydrous ethanol are highly correlated, moving together in a long run. Generally, the gap between them is explained

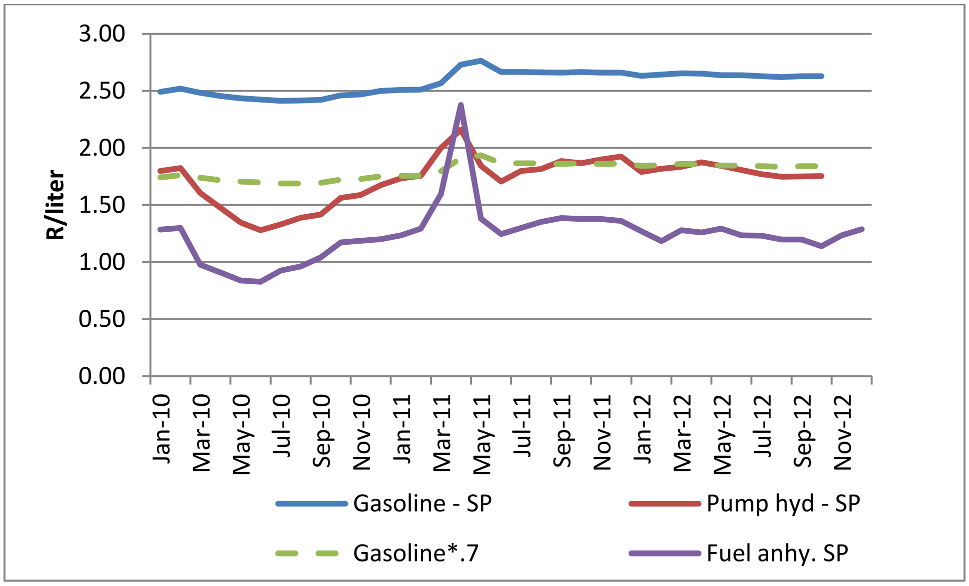
2 EIA official website: http://www.eia.gov/dnav/pet/pet_pri_rac_k_m.htm.

by the cost of dehydration, and the differences of the gaps in every year are resulted from the changes of dehydration process expenses in processing plants.

Sugar price, to some degree, has a link to the hydrous ethanol price and anhydrous ethanol price, but the changes of sugar price lag behind hydrous ethanol and anhydrous ethanol price. Since, sugar and ethanol are both produced from sugarcane, and right now most of the plants in Brazil can process both of them flexible, according to their relative prices. Therefore, when ethanol prices become more competitive, more sugarcane will be used to produce ethanol, and then price of sugar will change correspondingly. Also, we can see that the price of sugar tends to exhibit less volatility than the price of ethanol in most year periods.

To some degree, sugar price and ethanol price are related to the world crude oil price. With the dramatic change of energy price, the competition between sugar and ethanol has increased substantially. Soaring world crude oil price leads to increased demand for ethanol, which shifts sugarcane from the production of sugar to ethanol, thereby tightening sugar supplies and raising sugar price.

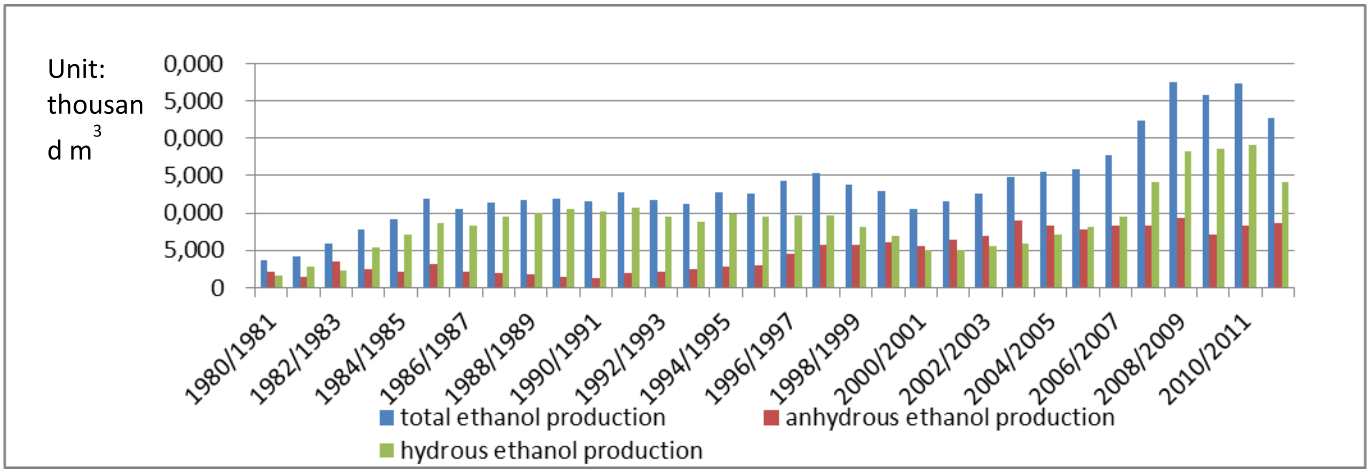
Chart 3.2 Comparison of gasoline C price and pump hydrous ethanol price



In Chart 3.2, we change the units to real per liter. The trend of gasoline C price is smoother than that using unit dollar per liter, indicating that Brazil's governments control its domestic gasoline C price, making it relative stable and irrespective of world crude oil price pattern. Also, according to the chart, we can see that hydrous ethanol price is rarely more than seventy percent of gasoline C price, which is consistent with its energy content and the ability of consumers to shift between fuels.

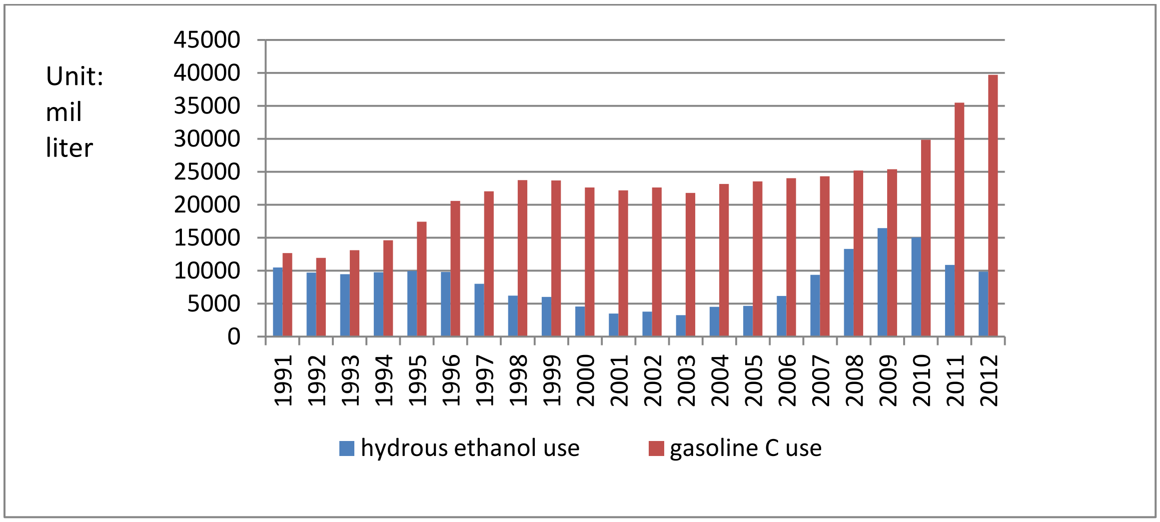
3.2 Discussion of Ethanol Production and Consumption

Chart 3.3 Total ethanol production, anhydrous ethanol production and hydrous ethanol production of Brazil



Brazilian ethanol production started in the 1970s in an attempt to find an alternative to fossil fuels. Since then ethanol production has been constantly on the rise as shown in Chart 3.3. The big breakthrough came after 2003. However, a combination of high world sugar prices, a poor sugarcane harvest, and underinvestment has caused a decline in ethanol production in 2011.

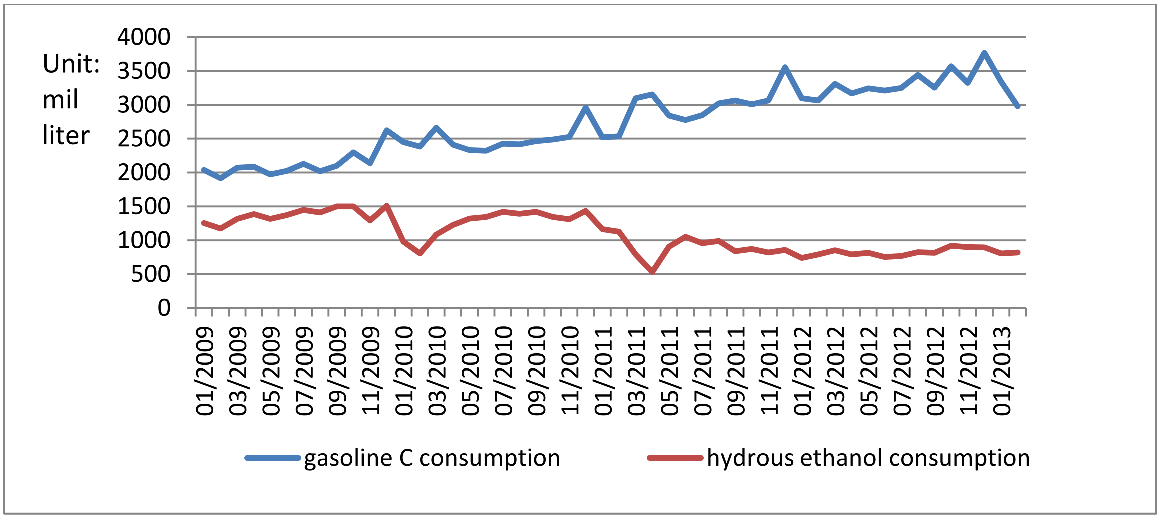
Chart 3.4 Hydrous ethanol use and gasoline use in Brazil



The usage of ethanol has increased substantially since 2003, but has fallen since 2010, as shown on Chart 3.4. Strong demand for ethanol is due to mandated ethanol in gasoline, robust sales of flexible fuel vehicles (FFV) (shown in Chart 3.6 and 3.7) and a favorable ethanol/gasoline price ratio. Despite production growth in the industry, the fact that forty-one of the country's roughly 400 sugarcane ethanol plants have closed has meant that ethanol supply lags demand. Then, domestic consumption of liquid ethanol in 2012 has been 26% lower than for the same period in 2008.

Moreover, changing patterns of hydrous ethanol and anhydrous ethanol differ. In the early 1990's, the production of hydrous ethanol was significantly more than that of anhydrous ethanol because of a large number of ethanol-only vehicles. After 2005, the production of hydrous ethanol increases dramatically, since the number of flex-fuel vehicles on the road has grown significantly (shown in Chart 3.3, 3.7 and 3.8).

Chart 3.5 Monthly data for gasoline C consumption and hydrous ethanol consumption



Additionally, observing monthly data for hydrous ethanol consumption and hydrous ethanol price, we can see in Chart 3.2 and Chart 3.5 that hydrous ethanol consumption response is sensitive to its price fluctuation. For example, in April 2011 the sharp rise in hydrous ethanol price gives rise to the dramatic fall in its consumption.

Chart 3.6 Accumulation number of Brazil's various car fleets

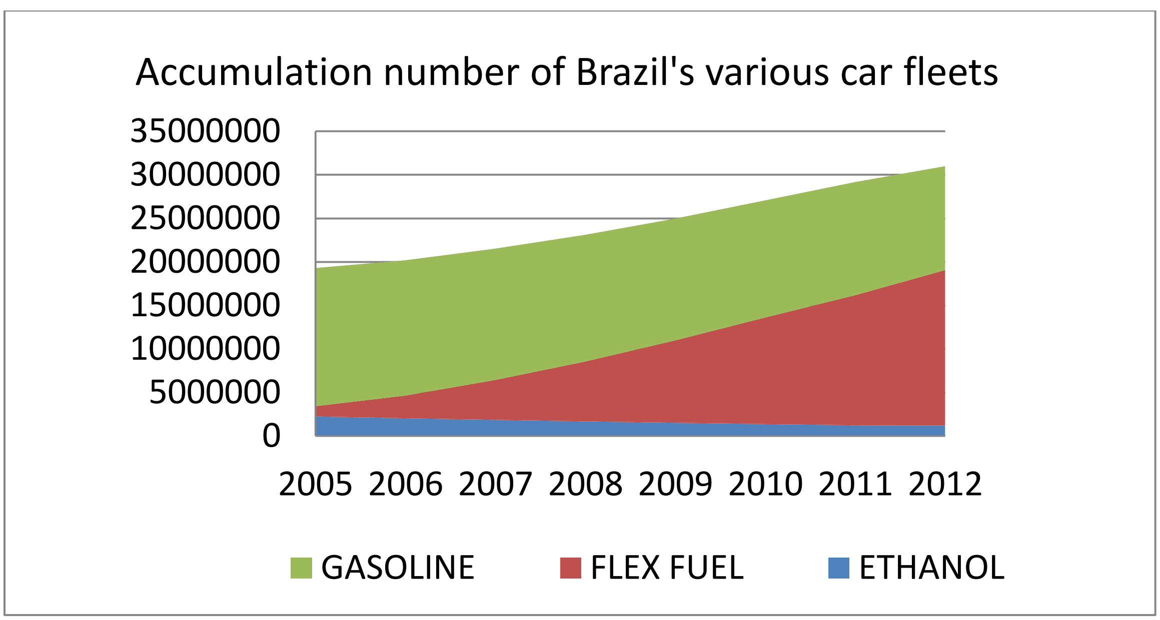
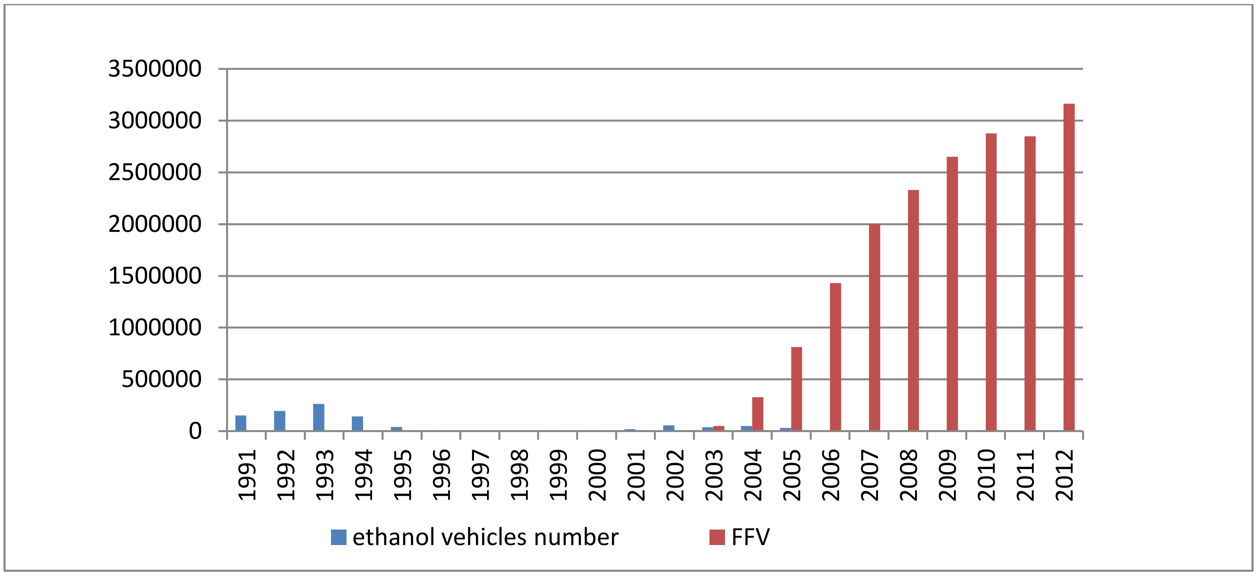


Chart 3.7 Brazil's ethanol vehicles and flex-fuel vehicles number for each year



Chapter 4 Brazil's ethanol and sugar model structure, estimation and simulation

4.1 Data Sources

All of the data used in this study were secondary data gathered from a variety of sources or calculated from other variables. They cover the period from 2000 to 2010. In order to make the regression results more precise, it would have been desirable to use a longer time series but given the different sources, this was the longest set of consistent data that could be assembled. There is no complete database for ethanol price, sugar price, sugarcane price, ethanol ending stock and ethanol consumption during 1990's. A complete list of variables outlining the source of the data and variable names is presented in Appendix A.

Data for sugarcane area planted, sugarcane area harvested, sugarcane production, and sugarcane demanded for sugar was obtained from USDA GAIN reports. Sugarcane yield is calculated by using sugarcane production divided by sugarcane area harvested. Sugar production divided by sugarcane used for sugar production served as the sugarcane to sugar conversion factor. Also, ethanol beginning stocks, ethanol production, total ethanol supply, ethanol domestic use, ethanol ending stocks and total utilization were gathered from USDA GAIN reports. Ethanol domestic demands are split into hydrous ethanol domestic use and anhydrous ethanol domestic use, according to comparable data from ANP and UNICA. Additionally, based on the consumption of anhydrous ethanol and the mandated blending ratio provided by USDA report, gasoline C consumption can be calculated directly.

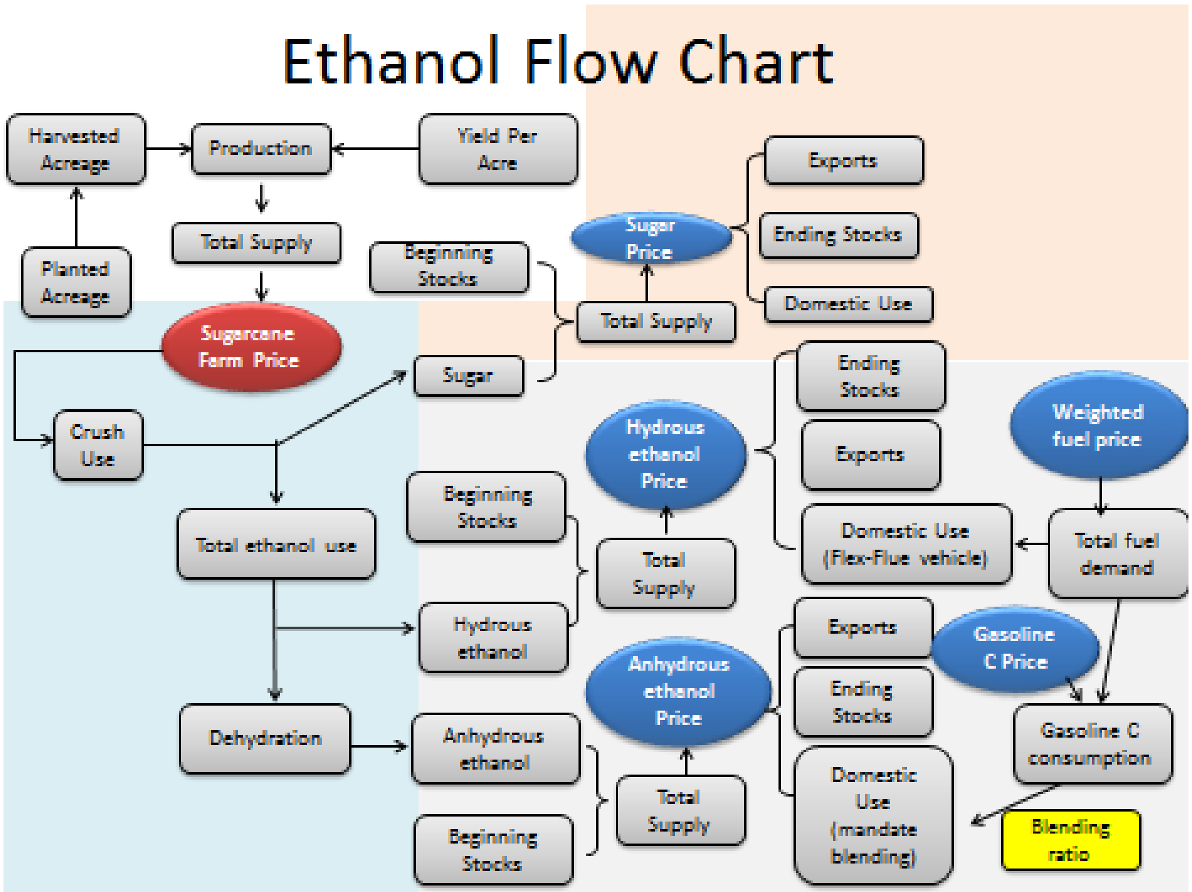
The sugarcane to ethanol conversion factor was calculated by total ethanol production divided by sugarcane used for ethanol production. Gasoline C price and hydrous ethanol price to consumers were from ANP, whose units are real/liter, and anhydrous ethanol price and hydrous ethanol price to producers were obtained from CEPEA, which use dollar/liter as the unit. Brazil's vehicle numbers by fuel type were from UNICA.

World sugar price, sugar domestic price, CPI, Brazil's exchange rate, Brazil's GDP and population, and world crude oil price were provided from FAPRI-MU model dataset, where world crude oil price was represented by refiners' crude oil acquisition price. Sugar production, sugar domestic use and sugar beginning stock data were supplied by USDA Production, Supply and Distribution table, and sugarcane price was from Consecana, sent by the researcher Paula Moura in ICONE. Moreover, all the projection data from 2011 to 2020, such as Brazil's exchange rate, CPI, GDP, population, US GDP deflator, Rest-of -World real GDP and population, world crude oil price, and numbers of FFV and total vehicles, were acquired from the FAPRI-MU model baseline.

4.2 Model Structure, Estimation and Simulation

Brazil's ethanol model is a non-spatial, multi-market model consisting of Brazil's sugarcane, sugar and ethanol markets. The model specifies sugarcane production and use, sugar production use and trade, and ethanol production, use and trade. The model incorporates linkages to the agricultural market and energy markets, namely Brazil's sugarcane, ethanol and gasoline markets. Figure 4.1 shows the structure of Brazilian sugar and ethanol markets.

Figure 4.1 Ethanol flow chart



The general structure of this model is made up of behavioral equations for production, consumption, ending stocks and net trade. The model closes for the world sugar price and world hydrous ethanol price, which is represented by Brazil's domestic hydrous ethanol price to producers, by making excess supply of sugar and ethanol from Brazil equal to excess demand from rest of the world. Meanwhile, domestic prices and international prices are linked by price transmission equations. Hydrous ethanol price and anhydrous ethanol price are linked through the price linkage equation.

Almost all the coefficients of equations were obtained by regression estimations. However, due to the data availability and policies impacts, certain regression results were unreasonable. In order to hold appropriate economic relationships and incorporate policies properly, I used my judgment to override some results and impose coefficients as well as elasticities, showing the particular economic relationships. Following are the specific behavior equations. The variable definitions and data sources are presented in Appendix A. The first section is price transmission equations. Brazil's domestic sugar price is linked to world sugar price through exchange rate. As mentioned before, Brazil is the world leader in sugar exports, and its exports have accounted for more than 50% percentage of the international market since 2011. On the basis of international theory and policy, Brazil can be classified as a large country with respect to sugar, so it through its implemented policies do effect the world price. Therefore, it is reasonable to apply the assumption that Brazilian domestic sugar price and international sugar price are highly related. Namely,

PDSUGAR=f(PWSUGAR)

The price transmission parameter of world sugar price is 1.106.

Also, Brazil's anhydrous ethanol price is linked to hydrous ethanol price to producers adding dehydration cost, and hydrous ethanol price to consumers is related to hydrous ethanol price to producers. Generally, the gap between anhydrous ethanol price and hydrous ethanol price is considered as cost of dehydration process. Thus, I do the regression of anhydrous ethanol price and summation of hydrous ethanol price to producers and dehydration cost, considering that random variance can explain omitted and invisible minor factors. Hydrous ethanol price to consumers is retail price at gasoline stations, and hydrous ethanol price to producers is the wholesale price at pump. It is obvious that these two prices are highly correlated.

The functions are:

PANETHN=f(PETHNPRD+CDEHYDR)

The price transmission parameter of hydrous ethanol price added dehydration cost is 1.173.

PETHNCON=f(PETHNPRD)

The price transmission parameter of hydrous ethanol price to producers is 0.946.

As for gasoline C price, it is explained by world crude oil price and anhydrous ethanol price, based on the composite of gasoline C. Unlike its competitors Exxon Mobil Corp and Royal Dutch Shell Plc, state-controlled Petrobras, which is not free to pass to rising oil prices to consumers at the pump, is constrained by government caps on how much it can charge consumers in Brazil. For instance, Petrobras cut gasoline price by 4.5% and diesel 15% in June 2009, and has not increased since the end of 2010. Here, I use the equation:

PGASO=f(PWOROIL, PANETHN)

I set the elasticity of anhydrous ethanol price 0.25, given the upper bound of required mix rate of anhydrous ethanol in pure gasoline. It means that one fourth of anhydrous ethanol movements are transmitted to Brazilian gasoline prices. In the meanwhile, based on the original regression of gasoline C price, the elasticity of world crude oil price is calculated is 0.35. This means that only about a third of world oil price movements are transmitted to Brazilian gasoline prices. There are a number of ways to deal with the transmission of the world crude oil price and to the gasoline C price. Relaxation of this assumption and the simulation of the model under different behaviors of the Brazilian government could be considered for future work.

In supply and demand equations, prices are expressed in real terms, adjusted by CPI.

4.3 Ethanol Sector

4.3.1 Ethanol Demand

Brazil's total ethanol demand is divided into hydrous ethanol demand and anhydrous ethanol demand. Their consumptions are determined by different economic incentives. Hydrous ethanol which contains water can be used directly by ethanol vehicles and flexible fuel vehicles, whereas anhydrous ethanol cannot be use directly by vehicles, and it is served as additives in gasoline C. Brazil's government sets the regulation regarding mandate mix of anhydrous ethanol in pure gasoline, so anhydrous ethanol is derived demand from gasoline C consumption use. Gasoline C is utilized by flexible fuel vehicles and gasoline vehicles.

Unlike the study of Tokgoz and Elobeid (2007), which estimates Brazil's demand for hydrous ethanol and anhydrous ethanol separately, I estimate Brazil's total fuel demand at first, considering the total fuel demand as total. Also, given the lower energy efficiency of ethanol, I estimate total fuel demand in the energy equivalent value, rather than physical units. Then, I estimate the share of hydrous ethanol consumption in total fuel demand, which allows the calculation of the amount of hydrous ethanol consumption. From these I can calculate the anhydrous ethanol domestic consumption and gasoline C domestic use.

As for the estimation of total fuel demand in the energy equivalent value, Brazil's GDP and weighted fuel price are introduced in the regression, where weighted fuel price is the combination of gasoline C price and hydrous ethanol price to consumers, using CPI doing adjustments and their consumption shares in the total fuel demand as weights respectively. The equations of energy equivalent value of total fuel demand and weighted fuel price are respectively expressed as follows:

EEDTOFUEL=f(BRZGDP, PWFUEL)

PWFUEL=(EECGASOC/ EEDTOFUEL)*(PGASO/CPI)+(EECDOHYETH/ EEDTOFUEL)*(PETHNCON/CPI)

Based on the calculation of coefficients, the elasticity of weighted fuel price is -0.363.

The calculation of weights is worthy of note. Given the energy equivalence, in other words, in order to supply equivalent energy as one liter pure gasoline does, 1.5 liter ethanol is needed, I use the energy equivalent quantity of ethanol consumption to calculate the weights. The transformation equations as follows:

EEDTOFUEL=EECGASOC + EECDOHYETH

EECGASOC= AGASOC+ CDOANHYETH/1.5

EECDOHYETH= CDOHYETH/1.5

where, energy equivalent quantity of total fuel demand is the summation of energy equivalent quantity of gasoline C consumption and energy equivalent quantity of hydrous ethanol consumption. Also, gasoline C consumption is the summation of gasoline A consumption and physical units of anhydrous ethanol consumption. In order to calculate the energy equivalent quantity of anhydrous ethanol consumption and energy equivalent quantity of hydrous ethanol consumption, the discount should be made on physical units of them. Thus, I use physical units of anhydrous ethanol consumption divided by 1.5 to represent energy equivalent quantity of anhydrous ethanol consumption. Similarly, energy equivalent quantity of hydrous ethanol consumption is represented by dividing physical units of hydrous ethanol consumption divided by 1.5.

Following part is the estimation of the share of hydrous ethanol consumption in total fuel demand. Since flex-fuel vehicles can choose between of hydrous ethanol and gasoline C the consumption of hydrous ethanol is highly sensitive to their relative prices. Also, because of its lower fuel efficiency, hydrous ethanol price is considered to be reasonable if it is no more than 70% the price of petroleum-based fuel. However, if hydrous ethanol price is more than 70% gasoline C price, consumers are likely to choose gasoline C rather than hydrous ethanol, which results in less use of hydrous ethanol. In order to reflect this market behavior, variable of the price trigger is introduced in this equation. According to the analysis above, the share equations is expressed as:

SCHYETH=f(PETHNCON/ PGASO, PTRIGGER, SFFV)

Same as the calculation of weighted fuel price of gasoline C and hydrous ethanol price, the calculation of share of hydrous ethanol consumption in total fuel demand also use the energy equivalent value of total fuel demand and energy equivalent value of hydrous ethanol domestic use. Based on the regression results, the elasticity of hydrous ethanol price is -0.543, and the elasticity of gasoline C price is 0.543.

Lastly, the equations for calculating the anhydrous ethanol domestic consumption and gasoline C domestic use are:

CDOANHYETH= RMANBLD* CGASOC

CGASOC= AGASOC+ EECDOANHYETH*1.5

4.3.2 Ethanol Supply

The share of sugarcane used in sugar production is used to determine the percentage of sugarcane used in sugar production and ethanol production, reflecting the interactions of these two markets. Mills in Brazil have become more flexible, indicating that they can produce both sugar and ethanol, switching between these two easily (Koizumi & Yanagishima, 2005).

Total ethanol production is calculated by multiplying the amount of sugarcane in ethanol production by conversion factor of sugarcane to ethanol.

The amount of sugarcane demanded in ethanol is calculated by share of sugarcane demanded for ethanol multiplying sugarcane production, and conversion factor of sugarcane to ethanol is the ratio of ethanol production and the amount of sugarcane used in ethanol production. Thus, the equation of total ethanol production is:

TETHPRO= SETHANOL* SUGCANPRO* CONVEFA

4.3.3 Inventory Demand and Net Export

The ethanol ending stock equation is constructed as

TETHEST=f(PANETHN/CPI, TETHPRO)

Brazil's ethanol net export

Net exports are derived as a residual, which is equal to production plus beginning stocks minus hydrous ethanol domestic use, minus anhydrous ethanol domestic use, minus total ethanol ending stock.

ETHNTEXP= TETHPRO+ TETHBST- CDOHYETH- CDOANHYETH- TETHEST

4.4 Sugar sector

4.4.1 Sugar Demand

Sugar domestic use is expressed by sugar domestic use per capita multiplied by population, and sugar domestic use per capita is determined by sugar domestic price and Brazilian income per capita. As for sugar ending stock, two variables that average of world sugar price and domestic sugar price and sugar production are involved in the model, based on the model equation of FAPRI. Therefore, sugar demand equations are:

CSUGPER=f(PDSUGAR/CPI, INCPER)

SUGESTK=f(average(PWSUGAR, PDSUGAR), SUGPRO)

The price elasticity of sugar demand is -0.036, and the elasticity of Brazilian income per capita is 0.344. These two elasticities from FAPRI-CARD are -0.08 and 0.15. It shows that in my model, domestic sugar use is more sensitive to Brazil's income change.

4.4.2 Sugar Supply

The sugar production equation is similar to that of ethanol production, which is determined by amount of sugarcane used in sugar production by conversion factor of sugarcane to sugar. Conversion factor is expressed by the ratio of sugar production and the amount of sugarcane used in ethanol production. Thus, the equation is

SUGPRO= SSUGAR* SUGCANPRO* CONVEFA

Sugarcane area harvested and sugarcane yield are used to determine sugarcane production, where sugarcane area harvested is expressed by sugarcane area planted. The lag of sugarcane area planted and lag of sugarcane price determine sugarcane area planted.

As for the sugarcane yield equation, the ratio of sugarcane area planted to sugarcane area harvested is introduced to indicate that how replanted crops affect yield. Sugarcane harvesting is done by stem cutting, in which the first cut is made 18 months after planting and then annually for five years, with yields decreasing for each of the five stubbles cuts (USDA 2011). Therefore, with the plants getting older, the yield will decline, whereas substituting older plants with new one will help to raise the yield, since the renewed crops cannot get harvested until 18 months later, which is equal to get rid of bad yield area for the first and half years. Thus, the more area crops are replanted, the bigger the ratio of sugarcane area planted to sugarcane area harvested, thereby resulting in higher yield. Also, the lag item of sugarcane price, which is determined by lag item of sugar domestic price and anhydrous ethanol price, should be involved in the sugarcane yield equation. So, the equations are shown:

ARSUGCAN=f(ARSUGCAN(t-1), PSUGCAN(t-1)/CPI)

In this equation, I set the coefficient of lag item of sugarcane area planted 0.8, since its estimated coefficient was more than 1, which resulted in an unacceptably long-run elasticity, from the regression. The area elasticity of lag item of sugarcane price is 0.022.

HARSUGCAN=f(ARSUGCAN)

YIDSUGCAN=f(LNTREND, ARSUGCAN/ HARSUGCAN, PSUGCAN(t-1)/CPI)

The elasticity of yield relative to sugarcane price is 0.049.

SUGCANPRO= HARSUGCAN* YIDSUGCAN

Another key variable needing to be determined is share of sugarcane demand for sugar, in order to calculate sugar production and ethanol production. In Brazil, right now there exists a large number of plants which are able to produce either sugar or ethanol (Valdes, 2011). Depending on the relative prices of sugar and ethanol, which is the main driving factor, these plants can switch between the production of sugar and ethanol flexibly (Tokgoz & Elobeid, 2007). Thus, variable of share of sugarcane demanded for sugar is appropriate to reflect instantaneous ethanol and sugar production adjustment corresponding to their relative prices (Koizumi & Yanagishima, 2005).

This equation is based on ratio of world sugar price and anhydrous ethanol price, and lag item of share of sugarcane demanded for sugar in this behavior equation. Thus, the equation is:

SSUGAR=f(PWSUGAR/PANETHN, SSUGAR(t-1))

For the same reason with the equation of sugarcane area planted, I set the coefficient of lag item of share of sugarcane 0.85, making it reasonable. According the regression, the elasticity of sugarcane demanded for sugar relative to world sugar price is 0.1603 and its elasticity relative to anhydrous ethanol price is -0.1603. The elasticity of ratio of ethanol to sugar price from the study written by Fabiosa et al. (2010) is 0.20. In my model Brazil's producers are less sensitive to relative prices of ethanol and sugar.

Brazil's sugar net export

Since Brazil does not import sugar, its net exports are equal to exports. It is derived as a residual, which is the same as net ethanol export:

SUGEXP= SUGPRO+ SUGBSTK- CONSUG- SUGESTK

4.5 Model Closure

Two approaches are used to close the model. Firstly, the entire world is considered as two parts: Brazil and the rest of world, so a Rest-of-World aggregate, indicating the rest of world demand for ethanol and sugar from Brazil, is involved to close the model.

Therefore, rest of world sugar net import from Brazil and rest of world ethanol net import from Brazil should be estimated. This study uses these two equations from FAPRI-MU model.

The equations are:

RESSUGIMP=f(PWSUGAR/DEFLUSG, PWSUGAR(t-1)/DEFLUSG, RESWGDP/RESWPOP, RESWPOP)

RESETHIMP=f(PANETHN, PWOROIL, RESWGDP/RESWPOP, RESWPOP)

The other approach to close the model system in this study is to link Brazil's model to U.S., EU model and the Rest-of-World as well. Under this closure the model is not limited to how Brazil's biofuel policy and fluctuation of world crude oil price affect itself, but also analyze how responses of U.S. and EU resulted from these shock affect Brazil.

Two identity equations close the domestic sugar and ethanol model.

For the first method, the identity equations are:

ETHNTEXP= RESETHIMP

SUGEXP= RESSUGIMP

Thus, the world sugar price is solved endogenously by equating excess supply in the world sugar market, namely Brazil's sugar net exports, to excess demand in the world sugar market, namely rest of world net sugar imports.

For ethanol, it solves for a representative world ethanol price, Brazilian hydrous ethanol price to producers, by equating excess supply, Brazilian ethanol net exports, and excess demand, rest of world net ethanol imports.

For the second method, the identity equations are:

ETHNTEXP= USETHNTIMP+ EUETHNTIMP+ RESWETHIMP

SUGEXP= USSUGIMP+ EUSUGIMP+ RESWSUGIMP

In short, with the exception of the equations of sugar ending stocks, rest of world demand for sugar from Brazil, and rest of world demand for ethanol from Brazil whose equation formulas and coefficients were obtained from FAPRI-MU model system, all the other equations were estimated by regression using historical data from marketing year 2000 to 2010. A combination of the results of the estimated equations plus modeler judgments was used in the final specification of the equations where the results of the initial estimation were unsatisfactory.

The model was simulated using the exogenous projections from the FAPRI system to produce a baseline of ten years of key variables. The results of this baseline, against which the results of the scenario will be compared, are presented in Appendix B.

4.6 Scenarios

Having laid out the basic modeling framework, this study moves on to an ex ante analysis using this historical simulation. The focus is on two key issues which are responsible for the biofuel boom in Brazil in recent years: the mandated blending ratio and the hike in crude oil prices. Detailed results from the scenarios are included in Appendix C.

As mentioned before, after 1999 Brazil's government has not set direct regulations on sugar and ethanol industry, but they continue to require a certain percentage usage of anhydrous ethanol mixed in all gasoline sold in Brazil. The government uses a blend ratio to adjust domestic gasoline and ethanol use. In 2003, the mandatory blend rates were set at a minimum of 20% and a maximum of 25%. Later, due to concerns of tight ethanol supply and rising prices resulted from unsatisfied sugarcane harvest, the lower limit was reduced to 18% in 2011. However, it is likely that the blend ratio is to rise to between 25% and 30% in the near future. Therefore, the first scenario this study focuses is setting blending ratio to 30%, analyzing the impact of a continued intensification of the use of biofuels in Brazil.

Another scenario is a crude oil price shock. It was the high crude oil price that creates an interest in finding alternative energy sources. High crude oil price have made ethanol production more profitable. Therefore, it is essential to analysis how world crude oil price affect the ethanol market and agricultural markets.

Chapter 5 Scenarios Results

5.1 Shock: blending ratio rises to 30%

5.1.1 Model one: close the model of Brazil and the rest of the world

Generally speaking, almost all results for all endogenous variables are in accord with my expectations. For instance, anhydrous ethanol price and gasoline C price go up as well as equilibrium international hydrous ethanol price. Ethanol production rises as the response of the ethanol price changes. Sugarcane production rises as well, but it needs two years to make the corresponding adjustment. The share of sugarcane used in sugar goes down, as more sugar is used for ethanol production.

When changing the blending ratio of 20% in baseline to 30% for simulation, the direct impact is the increase of anhydrous ethanol domestic use, and the percentage range for this increase is from 59.72% to 67.85%. The average increase is 64.27%.

Due to the sharp rise in anhydrous ethanol domestic consumption, the price of anhydrous ethanol moves upward by 6.62% on average, and the percentage range is from 1.33% to 15.90%.

Correspondingly, gasoline C price goes up as well by 1.94% on average, but the swing, from 0.42% to 4.52% , is less than that of anhydrous ethanol price, given the composite elements of gasoline C.

Table 5.1 Scenario result for model one shock one: setting mandate blending ratio to 30%

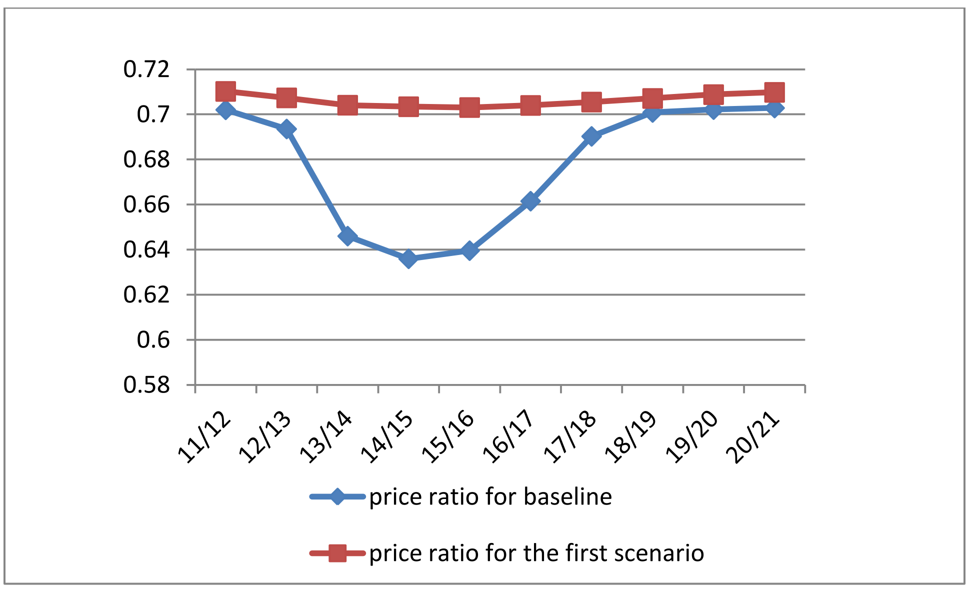
	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21	average
sugarcane area planted	0.00%	0.00%	0.03%	0.07%	0.23%	0.39%	0.50%	0.53%	0.47%	0.39%	0.26%
sugarcane area harvested	0.00%	0.00%	0.03%	0.06%	0.22%	0.37%	0.48%	0.50%	0.44%	0.37%	0.25%
sugarcane yield	0.00%	0.00%	0.09%	0.15%	0.60%	0.71%	0.66%	0.46%	0.19%	0.10%	0.30%
sugarcane production	0.00%	0.00%	0.12%	0.21%	0.82%	1.09%	1.14%	0.96%	0.64%	0.48%	0.55%
share of sugarcane demanded for sugar	-0.23%	-0.45%	-1.44%	-2.28%	-2.91%	-2.93%	-2.43%	-1.85%	-1.40%	-1.09%	-1.70%
sugarcane price	0.00%	1.31%	2.46%	11.09%	13.67%	12.93%	8.88%	3.62%	1.86%	1.87%	5.77%
sugar production	-0.23%	-0.45%	-1.33%	-2.07%	-2.11%	-1.88%	-1.31%	-0.91%	-0.77%	-0.62%	-1.17%
sugar domestic use	-0.03%	-0.05%	-0.16%	-0.22%	-0.20%	-0.17%	-0.11%	-0.08%	-0.07%	-0.05%	-0.11%
sugar ending stock	0.88%	2.54%	13.52%	25.31%	28.48%	26.11%	18.22%	14.52%	15.35%	13.93%	15.89%
sugar domestic price	0.54%	1.28%	5.22%	7.91%	7.68%	6.67%	4.25%	3.12%	2.88%	2.28%	4.18%
sugar export	-0.31%	-0.62%	-1.79%	-2.83%	-2.94%	-2.64%	-1.89%	-1.31%	-1.10%	-0.90%	-1.63%
world sugar demand for Brazil	-0.31%	-0.62%	-1.79%	-2.83%	-2.94%	-2.64%	-1.89%	-1.31%	-1.10%	-0.90%	-1.63%
equilibrium world sugar price	0.52%	1.21%	4.90%	7.41%	7.19%	6.26%	3.99%	2.93%	2.71%	2.15%	3.93%
total ethanol production	0.22%	0.43%	1.48%	2.32%	3.49%	3.74%	3.30%	2.58%	1.84%	1.41%	2.08%
gasoline C price	0.55%	0.93%	3.89%	4.52%	4.26%	2.85%	1.02%	0.42%	0.45%	0.47%	1.94%
weighted fuel price of gasoline C and hydrous ethanol price	3.41%	3.81%	7.55%	8.44%	7.94%	5.95%	3.46%	2.71%	2.87%	2.98%	4.91%
total fuel demand	-0.90%	-1.17%	-2.06%	-2.13%	-1.93%	-1.40%	-0.77%	-0.56%	-0.55%	-0.54%	-1.20%
share of hydrous ethanol consumption in total fuel demand	-37.22%	-29.67%	-18.32%	-15.79%	-13.96%	-15.86%	-19.50%	-21.96%	-24.24%	-25.74%	-22.23%
gasoline C domestic use	11.90%	11.09%	7.34%	6.74%	6.48%	7.81%	9.86%	10.83%	11.37%	11.74%	9.51%
hydrous ethanol domestic use	-37.79%	-30.49%	-20.01%	-17.58%	-15.62%	-17.04%	-20.12%	-22.39%	-24.66%	-26.15%	-23.18%
anhydrous ethanol domestic use	67.85%	66.63%	61.00%	60.11%	59.72%	61.71%	64.78%	66.25%	67.06%	67.61%	64.27%
total ethanol ending stock	-0.45%	-0.64%	-2.34%	-1.95%	-0.80%	0.48%	1.48%	1.42%	0.94%	0.67%	-0.12%
hydrous ethanol price to consumers	1.72%	2.94%	13.23%	15.61%	14.60%	9.45%	3.25%	1.31%	1.40%	1.46%	6.50%
anhydrous ethanol price	1.75%	2.99%	13.48%	15.90%	14.88%	9.62%	3.30%	1.33%	1.43%	1.49%	6.62%
Brazil's ethanol net export	-7.68%	-12.94%	-38.06%	-38.22%	-34.53%	-24.17%	-9.22%	-3.56%	-3.40%	-3.48%	-17.53%
rest of world net ethanol imports	-7.68%	-12.94%	-38.06%	-38.22%	-34.53%	-24.17%	-9.22%	-3.56%	-3.40%	-3.48%	-17.53%
equilibrium hydrous ethanol price to producers	1.77%	3.03%	13.66%	16.13%	15.08%	9.75%	3.35%	1.35%	1.44%	1.50%	6.71%

Generally speaking, it would be expected that the rise in gasoline C price should result in a decline in gasoline C domestic use. By contrast, gasoline C domestic use increases by 9.51% on average. The reason is the blending ratio shock of anhydrous ethanol domestic use also boosts the price of hydrous ethanol to consumers, and then the effect of price trigger makes its domestic use decline to a large degree. Hence, the substitution effect of gasoline C and hydrous ethanol dominates the whole change. Specifically, on average, the hydrous ethanol price to consumers goes up by 6.50%, whereas gasoline C price increases by 1.94%, namely, increase percentages of hydrous ethanol prices across projection periods are larger than those of gasoline C prices. Once the hydrous ethanol price is more than 70% of gasoline C price, consumption of hydrous ethanol is not economical, and consumers prefer to use gasoline C rather than hydrous ethanol, as energy content of gasoline per unit is equal to that of ethanol per 1.5 unit. Additionally, owing to a boost of FFV use, whose fuel consumption can switch between gasoline C and hydrous ethanol flexibly, making them very sensitive to relative prices of those two series of fuels. Therefore, there is a significant switch to use gasoline C rather than hydrous ethanol.

Moreover, another conclusion can be drawn in that there are two direct contributions to the sharp increase in anhydrous ethanol domestic consumption. One of them is the mandated blending ratio shock. The other is the rise of gasoline C domestic use resulting from the substitution effect.

Moreover, it is found that hydrous ethanol domestic use declines more significantly at the beginning and at the end of the period, namely during 11/12, 12/13 and 18/19 to 20/21, than those in other years of the projection period. Because during 11/12, 12/13 and 18/19 to 20/21, the baseline shows that the price ratios of hydrous ethanol and gasoline C are more than 0.7 and the price trigger works, making the domestic use of hydrous ethanol decline. However, during the rest years across projection period, price ratios of hydrous ethanol and gasoline C are less than 0.7, so the price triggers do not have any effects on hydrous ethanol domestic use. Once affected by the blending ratio shock, hydrous ethanol domestic consumptions are subjected to more dramatic adjustments during 11/12, 12/13 and 18/19 to 20/21 than those in other years, via price trigger mechanism.

Chart 5.1 Price ratios for baseline and the first scenario



In addition, the increase of hydrous ethanol price results from the fall in its net exports. A 10% rising of anhydrous ethanol blended in gasoline C leads to an average 64.27% increase of its domestic use, which is larger than the decline of hydrous ethanol domestic use, whose domestic consumption declines by 23.18% on average. Thus, overall ethanol domestic use rises significantly, reducing its exports. Because Brazil is a large ethanol exporter, the change of its ethanol exports may have significant impact on international ethanol price, and its domestic ethanol price can be considered as the representative of world ethanol price. Therefore, the reduction of ethanol net export results in the increase of international ethanol price, namely equilibrium hydrous ethanol price to producers.

With the rise of both hydrous ethanol price and anhydrous ethanol price, total ethanol production goes up by 2.08%. Therefore, in the sugar market, more sugarcane is used to produce ethanol, and the result shows that the share of sugarcane demanded for sugar declines by 1.70% in average term, and the percentage range is from 0.23% to 2.93%.

Sugar production falls as well from 0.23% to 2.11% and its domestic consumption decreases less across all projection period, whereas its ending stock has a dramatic increase. Thus, the export of sugar falls and the world sugar price rise, given Brazil is the largest sugar exporter. Through the price transmission, sugar domestic price goes up accordingly.

5.1.2 Model two: close the model of Brazil, U.S., EU and the rest of the world

In this section, I consider the same shock as the previous one, but use the model in conjunction with FAPRI's models of Brazil, U.S., EU, and rest of the world. Then, I compare the results of model two with those in model one. The difference in results reflects a qualitative difference since the reduced form model used in the Model one is a simplification of the world system. The difference in results also reflects that the reduced form model that was provided by Dr. Binfield is not an accurate representation of the actual FAPRI system.

The movement directions of all variables in model two are consistent with those of variables in model one.

As before, anhydrous ethanol domestic use rises, but the average change range in this model, which is 60.74%, is less than that in model one. Gasoline C domestic use increase by a smaller magnitude, which is 7.16% in the average term, comparing with that in model one. Also, hydrous ethanol domestic use declines by a smaller degree, which is 15.45%, than that in model one. However, a 7.50% increase in anhydrous ethanol price on average is larger than that in model one, which is 6.62%. Similarly, the rise in hydrous ethanol price to consumers is 7.37%, the increase in gasoline C price is 2.17%, and the rise in equilibrium hydrous ethanol price to producers is 7.61%. All of them are larger than those in model one.

Table 5.2 Scenario result of Brazil for model two shock one: setting mandate blending ratio to 30%

	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21	average
sugarcane area planted	0.00%	0.00%	0.03%	0.05%	0.26%	0.39%	0.47%	0.54%	0.49%	0.41%	0.29%
sugarcane area harvested	0.00%	0.00%	0.03%	0.05%	0.24%	0.37%	0.45%	0.51%	0.47%	0.39%	0.28%
sugarcane yield	0.00%	0.00%	0.09%	0.09%	0.73%	0.64%	0.58%	0.57%	0.25%	0.09%	0.34%
sugarcane production	0.00%	0.00%	0.12%	0.13%	0.97%	1.01%	1.03%	1.08%	0.72%	0.48%	0.62%
share of sugarcane demanded for sugar	-0.23%	-0.27%	-1.66%	-2.46%	-3.02%	-3.17%	-2.67%	-2.07%	-1.54%	-1.17%	-2.00%
sugarcane price	0.00%	1.31%	1.47%	14.18%	12.42%	11.36%	11.52%	4.87%	1.62%	1.68%	6.72%
sugar production	-0.23%	-0.27%	-1.55%	-2.33%	-2.08%	-2.19%	-1.66%	-1.01%	-0.83%	-0.70%	-1.40%
sugar domestic use	-0.03%	-0.03%	-0.17%	-0.17%	-0.16%	-0.20%	-0.13%	-0.07%	-0.07%	-0.05%	-0.12%
sugar ending stock	0.88%	2.05%	15.25%	22.06%	22.07%	30.50%	21.07%	12.29%	13.20%	12.26%	16.75%
sugar domestic price	0.54%	1.06%	5.85%	6.42%	6.27%	8.50%	5.36%	2.85%	2.92%	2.40%	4.63%
sugar export	-0.31%	-0.39%	-2.12%	-3.30%	-2.97%	-3.12%	-2.44%	-1.50%	-1.21%	-1.04%	-2.01%
world sugar demand for Brazil	-0.31%	-0.39%	-2.12%	-3.30%	-2.97%	-3.12%	-2.44%	-1.50%	-1.21%	-1.04%	-2.01%
equilibrium world sugar price	0.52%	0.99%	5.46%	5.98%	5.86%	7.94%	5.02%	2.68%	2.74%	2.26%	4.33%
total ethanol production	0.22%	0.25%	1.61%	2.26%	3.58%	3.68%	3.24%	2.78%	1.96%	1.41%	2.31%
gasoline C price	0.55%	0.50%	4.90%	4.17%	3.79%	3.61%	1.41%	0.35%	0.37%	0.42%	2.17%
weighted fuel price of gasoline C and hydrous ethanol price	3.41%	3.17%	8.04%	6.96%	6.25%	6.24%	3.50%	2.29%	2.33%	2.71%	4.61%
total fuel demand	-0.90%	-0.98%	-2.15%	-1.76%	-1.53%	-1.44%	-0.77%	-0.47%	-0.45%	-0.49%	-1.12%
share of hydrous ethanol consumption in total fuel demand	-37.22%	-30.36%	-6.59%	-6.38%	-4.43%	-6.53%	-13.65%	-18.68%	-20.59%	-22.92%	-14.46%
gasoline C domestic use	11.90%	11.24%	3.46%	3.83%	3.43%	4.36%	7.69%	9.64%	9.81%	10.96%	7.16%
hydrous ethanol domestic use	-37.79%	-31.04%	-8.60%	-8.03%	-5.89%	-7.88%	-14.31%	-19.06%	-20.95%	-23.30%	-15.45%
anhydrous ethanol domestic use	67.85%	66.87%	55.19%	55.75%	55.15%	56.54%	61.53%	64.46%	64.72%	66.44%	60.74%
total ethanol ending stock	-0.45%	-0.33%	-2.96%	-1.67%	-0.36%	0.02%	1.24%	1.61%	1.08%	0.71%	-0.07%
hydrous ethanol price to consumers	1.72%	1.57%	17.14%	14.32%	12.94%	12.25%	4.52%	1.10%	1.14%	1.32%	7.37%
anhydrous ethanol price	1.75%	1.60%	17.47%	14.59%	13.18%	12.47%	4.60%	1.12%	1.16%	1.34%	7.50%
Brazil's ethanol net export	-7.68%	-13.21%	-98.33%	-78.76%	-75.69%	-72.01%	-42.37%	-21.44%	-23.46%	-17.39%	-49.18%
rest of world net ethanol imports	-7.68%	-13.21%	-98.33%	-78.76%	-75.69%	-72.01%	-42.37%	-21.44%	-23.46%	-17.39%	-49.18%
equilibrium hydrous ethanol price to producers	1.77%	1.62%	17.72%	14.79%	13.36%	12.65%	4.66%	1.14%	1.18%	1.36%	7.61%

The central difference from model two to model one is that in model one the change of Brazil's ethanol net export simply results from the relative changes of domestic ethanol production and consumption caused by the shock, whereas in this model the outside shock also affect U.S. and EU ethanol net imports through the fluctuation of the international ethanol price, thereby having impacts on Brazil's net exports. Namely, the shock also has implicit effects on Brazilian ethanol net exports based on the change of relative domestic and international ethanol prices resulted from the adjustments of U.S. and EU ethanol markets as the feedback.

In model two, Brazil's ethanol net exports decline by 49.18% on average, which is larger than 17.53% in model one. This result means that the shock of raising blending ratio by 10% affects Brazil's ethanol price and sugar price, resulting in the fluctuation of international ethanol price and world sugar price.

Both U.S. and EU respond by adjusting their imports and exports. Therefore, three aspects, changes of Brazilian ethanol production and use, U.S. ethanol and EU ethanol net import lead to more dramatic reduction of Brazil's ethanol net export.

Here, some key variables for U.S. and EU are picked up from the model. The direct impact of rise in international hydrous ethanol price resulted from Brazilian mandated blending shock to U.S. ethanol market is that U.S. ethanol net imports decline dramatically, by 55.21% on average. Because increasing international hydrous ethanol price makes U.S. corn –based ethanol price more competitive, and then demand for U.S. corn ethanol exports increase.

Besides, stronger demand for U.S. corn ethanol exports pulls up its price, which increases ethanol producers' margins, thereby spurring its production by 2.15% on average as well.

Table 5.3 Scenario result of U.S. for model two shock one: setting mandate blending ratio to 30%

	Baseline	blending ratio shock	absolute value of the difference	relative difference
Ethanol Production	65,704	67,115	1,411	2.15%
Ethanol Consumption	63,390	63,666	276	0.44%
Ethanol Net trade	-1,142	-511	630	-55.21%
Conv. rack	2.29	2.35	0.06	2.77%
Conv. RIN	0.71	0.77	0.06	9.02%
Adv. RIN	1.52	1.60	0.08	5.12%

Table 5.4 Scenario result of EU for model two shock one: setting mandate blending ratio to 30%

	Baseline	blending ratio shock	absolute value of the difference	relative difference
Ethanol Production	6290	6375	85	1.35%
Ethanol Consumption	7586	7510	-76	-1.00%
Ethanol Net trade	-1296	-1135	160	-12.38%

At these relative ethanol and gasoline prices the biofuel mandate in the RFS is a fixed mandate, irrespective of price. So the consumption of ethanol in U.S. just rises a little bit, 0.44% on average.

Due to the rise in U.S. ethanol price to producers which results in less profits for blenders, blenders prefer to purchase RIN rather than buying ethanol and mixing in gasoline. Hence, the conventional ethanol RIN market becomes more competitive, pulling up RIN price. The same thing happens in advanced ethanol RIN market, since Brazilian sugarcane ethanol accounts for a large part in U.S. advanced ethanol market, and Brazilian mandated blending shock give rise to the increase in international hydrous ethanol price.

As for the EU market, their net ethanol imports fall as well, by 12.38% on average. Since the increase in international hydrous ethanol price leads to a 1.00% decline in ethanol consumption in EU and stimulate domestic ethanol production increase by 1.35% on average. EU substitutes its consumption of Brazilian ethanol with its own ethanol.

For sugar, all the endogenous variables change more drastically, comparing with those in model one. Specifically, the share of sugarcane demanded for sugar goes down by 2.00% on average, comparing with 1.70% in model one. Sugar production declines by 1.40% in average term, comparing with 1.17% in model one. A 0.12% reduction in sugar domestic use is less than that in model one, which is 0.11%. The fluctuations of international sugar export and import lead to a rise in equilibrium world sugar price by 4.33%, comparing with 3.93% in model one. Accordingly, sugar domestic price increases by 6.72% and it is 5.77% in model one.

The results in this model illustrate that the equilibrium world sugar price and equilibrium hydrous ethanol price, namely world ethanol price, are impacted by and impact not only Brazilian markets, but also U.S. and EU markets, causing these two endogenous variables fluctuating more drastically.

5.2 Shock: world crude oil price increases by 20%

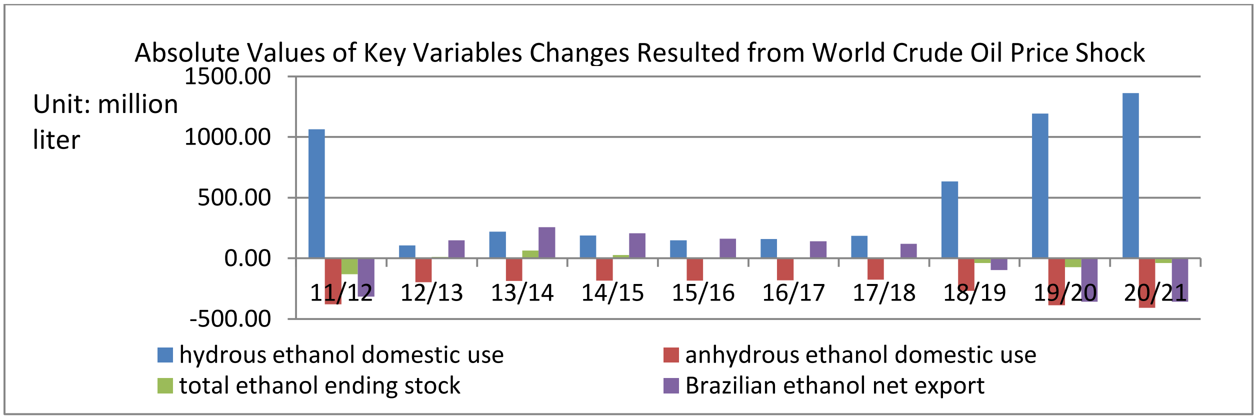
5.2.1 Model one: close the model of Brazil and the rest of the world

A 20% increase of world crude oil price results in the 8.58% rise in gasoline C price, because given the composite of gasoline C, its price is explicitly dictated by the price of crude oil, although it is assumed that all of the price change is not passed on to the Brazilian consumer. Then, gasoline C domestic use is predicted to decrease by 2.84% on average, which causes anhydrous ethanol domestic use to decline by the same magnitude. Accordingly, hydrous ethanol domestic consumption is projected to rise by 2.56% on average because with higher crude oil prices, biofuels are substituted for petroleum products. Higher crude oil prices act as an incentive for increased biofuels consumption (Birur, Hertel, & Tyner, 2008).

Table 5.5 Scenario result for model one shock two: a 20% rise in world crude oil price

	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21	average
sugarcane area planted	0.00%	0.00%	0.13%	0.13%	0.09%	0.07%	0.07%	0.07%	0.07%	0.11%	0.07%
sugarcane area harvested	0.00%	0.00%	0.13%	0.12%	0.08%	0.07%	0.07%	0.06%	0.06%	0.11%	0.07%
sugarcane yield	0.00%	0.00%	0.44%	0.08%	-0.03%	0.02%	0.04%	0.05%	0.05%	0.21%	0.08%
sugarcane production	0.00%	0.00%	0.56%	0.19%	0.05%	0.09%	0.11%	0.11%	0.12%	0.32%	0.15%
share of sugarcane demanded for sugar	-1.05%	-0.80%	-0.62%	-0.39%	-0.31%	-0.30%	-0.31%	-0.63%	-1.23%	-1.67%	-0.73%
sugarcane price	0.00%	6.33%	1.20%	-0.64%	0.29%	0.77%	0.88%	0.98%	4.16%	8.40%	2.24%
sugar production	-1.05%	-0.80%	-0.07%	-0.20%	-0.26%	-0.21%	-0.20%	-0.52%	-1.11%	-1.36%	-0.58%
sugar domestic use	-0.12%	-0.06%	0.01%	-0.03%	-0.02%	-0.02%	-0.02%	-0.06%	-0.11%	-0.12%	-0.06%
sugar ending stock	4.09%	3.70%	-0.39%	3.04%	3.48%	2.92%	3.03%	9.83%	24.60%	31.95%	8.63%
sugar domestic price	2.52%	1.68%	-0.32%	1.04%	0.93%	0.74%	0.74%	2.31%	4.86%	5.39%	1.99%
sugar export	-1.46%	-1.16%	-0.13%	-0.26%	-0.36%	-0.30%	-0.28%	-0.72%	-1.55%	-1.94%	-0.82%
world sugar demand for Brazil	-1.46%	-1.16%	-0.13%	-0.26%	-0.36%	-0.30%	-0.28%	-0.72%	-1.55%	-1.94%	-0.82%
equilibrium world sugar price	2.41%	1.59%	-0.30%	0.97%	0.87%	0.70%	0.70%	2.17%	4.57%	5.08%	1.87%
total ethanol production	1.03%	0.77%	1.18%	0.57%	0.33%	0.35%	0.38%	0.65%	1.15%	1.72%	0.81%
gasoline C price	10.28%	8.02%	7.82%	7.95%	8.05%	7.88%	7.58%	8.52%	9.83%	9.85%	8.58%
weighted fuel price of gasoline C and hydrous ethanol price	9.34%	6.50%	5.90%	6.14%	6.35%	6.22%	5.99%	7.37%	9.29%	9.27%	7.24%
total fuel demand	-2.45%	-1.99%	-1.61%	-1.55%	-1.55%	-1.46%	-1.33%	-1.53%	-1.77%	-1.69%	-1.69%
share of hydrous ethanol consumption in total fuel demand	10.05%	2.69%	2.86%	2.52%	2.28%	2.21%	2.16%	4.27%	6.89%	7.43%	4.34%
gasoline C domestic use	-4.56%	-2.49%	-2.30%	-2.19%	-2.14%	-2.06%	-1.95%	-2.85%	-3.89%	-3.97%	-2.84%
hydrous ethanol domestic use	7.35%	0.65%	1.20%	0.94%	0.70%	0.72%	0.80%	2.68%	5.00%	5.61%	2.56%
anhydrous ethanol domestic use	-4.56%	-2.49%	-2.30%	-2.19%	-2.14%	-2.06%	-1.95%	-2.85%	-3.89%	-3.97%	-2.84%
total ethanol ending stock	-2.23%	0.19%	0.91%	0.36%	0.07%	0.04%	0.04%	-0.47%	-0.90%	-0.46%	-0.24%
hydrous ethanol price to consumers	8.34%	0.93%	-0.75%	-0.04%	0.68%	0.90%	1.03%	4.75%	9.53%	9.54%	3.49%
anhydrous ethanol price	8.49%	0.95%	-0.77%	-0.04%	0.69%	0.92%	1.05%	4.83%	9.70%	9.70%	3.55%
Brazil's ethanol net export	-22.75%	10.58%	12.89%	9.27%	7.09%	6.51%	6.01%	-4.78%	-16.14%	-15.81%	-0.71%
rest of world net ethanol imports	-22.75%	10.58%	12.89%	9.27%	7.09%	6.51%	6.01%	-4.78%	-16.14%	-15.81%	-0.71%
equilibrium hydrous ethanol price to producers	8.60%	0.96%	-0.78%	-0.04%	0.70%	0.93%	1.07%	4.89%	9.82%	9.82%	3.60%

Chart 5.2 Absolute values of key variables changes resulted from world crude oil price shock



It is worth noticing that the increase percentages of hydrous ethanol domestic use at the beginning and at the end of the entire projection period, namely 11/12 and 18/19 to 20/21, are significantly larger than those during rest years. The reason is that in the baseline the price ratios of hydrous ethanol and gasoline C are more than 0.7 during the beginning and the end years, so the prices triggers work, adjusting hydrous ethanol domestic consumption lower, whereas price triggers do not have effects on hydrous ethanol use for the rest years across the projection period. Once the rise in world crude oil shocks the whole system, making the gasoline C price go up, the price triggers boost hydrous ethanol consumption during the beginning and the end, since hydrous ethanol and gasoline C price ratios are lower than 0.7. However, there is no consumption change resulted from price triggers for the rest of the years, so their rises in use are not remarkable, comparing with those in 11/12 and 18/19 to 20/21.

Since, there are big switches from anhydrous ethanol consumption to hydrous ethanol use at the beginning and the end across the entire projection period, anhydrous ethanol domestic use declines more drastically during those periods, compared with those in the other years. Also, total ethanol ending stocks go down in 11/12 and 18/19 to 20/21, whereas go up in the other years.

Given the change directions and trends of hydrous ethanol domestic use, anhydrous ethanol consumption and total ethanol ending stock, percentage changes of Brazilian ethanol net exports during the projection period follow the patterns of total ethanol ending stock, namely Brazil's net exports decline in 11/12 and 18/19 to 20/21, and go up in the rest of the years. Accordingly, the equilibrium hydrous ethanol price rises dramatically in 11/12 and 18/19 to 20/21, but goes up relatively little, and even has a small reduction for the rest of the years. The reason that hydrous ethanol price to consumers, anhydrous ethanol price and equilibrium hydrous ethanol price to producers declines a bit in the marketing year 13/14 and 14/15 is that ethanol production rises sharply by 1.18% in 13/14, comparing to those in other projection periods. Although rise of world crude oil price makes a remarkable switch from gasoline C use to hydrous ethanol use in 11/12, sugarcane area planted, share of sugarcane demanded for sugar, and the ethanol production cannot respond to this change sufficiently and immediately, and their adjustments lag behind those in ethanol consumption.

There is a significant difference between these two shocks. As for the first shock, there is no direct effect on the Rest-of-World part, so the model just makes adjustments according to the change of Brazilian sugar and ethanol market resulting from the outside shock, and responding to international sugar and ethanol prices as feedbacks.

However, the second stock, rising world crude oil price by 20%, not only has impacts on Brazilian sugar and ethanol markets, but also results in the increase of net ethanol import from rest of the world. Consequently, the percent change of Brazil's ethanol net export is impacted not only by domestic ethanol production and use, but by the pull from demand side as well. Finally, an increase in world crude oil price results in an average 3.60% rise in the equilibrium hydrous ethanol price.

The increase in hydrous ethanol price leads to a 0.81% rise in total ethanol production, thereby making the share of sugarcane demanded for sugar decline by 0.73%. Thus, sugar production has a 0.58% reduction. Besides, with sugar ending stock rising 8.63%, and a 0.06% decrease of sugar domestic use, sugar exports are predicted to decline by 0.82%. As the world's leading producer and exporter of sugar, Brazil plays an increasingly important role in establishing global sugar prices. Consequently, the international sugar price goes up by 1.87% in response to Brazil’s fall in sugar exports, compared to a 3.60% rise in international ethanol price. We can see that the change percentage of sugar price is much smoother than that of ethanol price, just about half of that of ethanol price. It is in accord with historical trend of sugar and ethanol price displaying in the chart 3.1. Meanwhile, its domestic sugar price is projected to rise by 1.99% on average.

5.2.2 Model two: close the model of Brazil, US, EU and the rest of the world

For the ethanol markets, the percentage changes of only two endogenous variables, share of hydrous ethanol consumption in total fuel demand and hydrous ethanol domestic use, are less than those in model one. All the other variables change in a larger degree, compared to those in model one.

Table 5.6 Scenario result for model two shock two: a 20% rise in world crude oil price

	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21	average
sugarcane area planted	0.00%	0.00%	0.00%	0.04%	0.06%	0.08%	0.10%	0.13%	0.14%	0.19%	0.08%
sugarcane area harvested	0.00%	0.00%	0.00%	0.04%	0.06%	0.07%	0.09%	0.13%	0.13%	0.18%	0.08%
sugarcane yield	0.00%	0.00%	0.00%	0.13%	0.10%	0.09%	0.13%	0.20%	0.13%	0.27%	0.12%
sugarcane production	0.00%	0.00%	0.00%	0.17%	0.16%	0.16%	0.23%	0.32%	0.26%	0.45%	0.20%
share of sugarcane demanded for sugar	0.00%	-0.22%	-0.39%	-0.49%	-0.62%	-0.80%	-0.82%	-1.14%	-1.58%	-1.95%	-0.89%
sugarcane price	0.00%	0.00%	2.20%	2.00%	1.77%	2.64%	3.96%	2.56%	5.45%	8.35%	3.22%
sugar production	0.00%	-0.22%	-0.39%	-0.33%	-0.46%	-0.64%	-0.59%	-0.82%	-1.32%	-1.50%	-0.70%
sugar domestic use	0.00%	-0.03%	-0.03%	-0.02%	-0.04%	-0.06%	-0.05%	-0.07%	-0.12%	-0.12%	-0.06%
sugar ending stock	0.00%	1.74%	3.02%	3.18%	5.47%	9.22%	7.52%	12.16%	22.67%	27.48%	10.27%
sugar domestic price	0.00%	0.92%	1.01%	0.94%	1.66%	2.62%	1.92%	3.18%	5.22%	5.53%	2.55%
sugar export	0.00%	-0.30%	-0.55%	-0.47%	-0.64%	-0.90%	-0.86%	-1.18%	-1.90%	-2.20%	-1.00%
world sugar demand for Brazil	0.00%	-0.30%	-0.55%	-0.47%	-0.64%	-0.90%	-0.86%	-1.18%	-1.90%	-2.20%	-1.00%
equilibrium world sugar price	0.00%	0.86%	0.95%	0.87%	1.55%	2.45%	1.79%	2.98%	4.90%	5.19%	2.39%
total ethanol production	0.00%	0.20%	0.34%	0.60%	0.69%	0.83%	0.90%	1.24%	1.52%	2.00%	0.92%
gasoline C price	0.00%	8.52%	8.81%	8.54%	8.69%	8.95%	8.14%	8.96%	9.74%	9.82%	8.91%
weighted fuel price of gasoline C and hydrous ethanol price	0.00%	7.16%	7.45%	7.12%	7.41%	7.95%	6.87%	7.99%	8.73%	9.05%	7.75%
total fuel demand	0.00%	-2.22%	-1.99%	-1.80%	-1.81%	-1.83%	-1.51%	-1.66%	-1.67%	-1.65%	-1.79%
share of hydrous ethanol consumption in total fuel demand	0.00%	3.86%	2.05%	2.06%	1.79%	1.41%	1.75%	4.80%	11.59%	8.94%	4.25%
gasoline C domestic use	0.00%	-2.99%	-2.37%	-2.25%	-2.20%	-2.10%	-1.96%	-3.13%	-5.20%	-4.49%	-2.97%
hydrous ethanol domestic use	0.00%	1.56%	0.02%	0.22%	-0.06%	-0.45%	0.21%	3.07%	9.72%	7.15%	2.38%
anhydrous ethanol domestic use	0.00%	-2.99%	-2.37%	-2.25%	-2.20%	-2.10%	-1.96%	-3.13%	-5.20%	-4.49%	-2.97%
total ethanol ending stock	0.00%	-0.68%	-0.33%	-0.06%	-0.16%	-0.29%	0.06%	-0.31%	-0.58%	-0.23%	-0.29%
hydrous ethanol price to consumers	0.00%	2.62%	2.34%	2.04%	2.93%	4.33%	2.72%	6.13%	9.27%	9.44%	4.64%
anhydrous ethanol price	0.00%	2.66%	2.39%	2.08%	2.98%	4.41%	2.76%	6.23%	9.43%	9.60%	4.73%
Brazil's ethanol net export	0.00%	3.70%	11.90%	10.07%	13.61%	20.82%	14.37%	1.68%	-28.06%	-19.66%	3.16%
rest of world net ethanol imports	0.00%	3.70%	11.89%	10.06%	13.61%	20.82%	14.36%	1.68%	-28.06%	-19.66%	3.15%
equilibrium hydrous ethanol price to producers	0.00%	2.70%	2.42%	2.11%	3.02%	4.47%	2.80%	6.31%	9.55%	9.72%	4.79%

The gasoline C price increases by 8.91% in response to a 20% rise in world crude oil price, which is larger than 8.58% in model one. Gasoline C domestic use declines by 2.97% as a result of rise in gasoline C price, which is more than 2.84% in model one. At the same time, anhydrous ethanol domestic use declines by the same degree as gasoline C consumption. Hydrous ethanol domestic use has a 2.38% increase, which is less than 2.56% in model one. Since, gasoline C domestic use decreases by a larger percent than that hydrous ethanol rises, total fuel demand decreases as well, by 1.79% , which is a little more than the 1.69% seen in model one.

It is crucial to note that Brazilian ethanol net exports go up by 3.16% on average, which is opposite to that in model one. In model one, the Brazilian ethanol net export declines by 0.71% in the average term. The reason is in model one the projection period is 11/12 to 20/21, whereas in model two the projection period is 12/13 to 20/21, and 11/12 is not involved. Brazilian ethanol exports increase by 1.49% on average in model one for the same time horizon. Thus, in essence, the movement directions of Brazilian ethanol net export in these two models are the same. In addition, the change patterns and trend of Brazilian ethanol net export are consistent.

With respect to the sugar market, the changes for all the endogenous variables are larger than those in model one, with the exception of sugar domestic use, whose average change percentage is the same as that in model one. Specifically, share of sugarcane demanded for sugar declines by 0.89%, comparing with 0.73% in model one. Sugar production also has a 0.70% reduction, comparing with 0.58% in model one. In addition, Brazilian sugar price rises by 2.55%, comparing with 1.99% in model one. Accordingly, the international sugar price goes up by 2.39%, compared to 1.87% in model one. Besides, sugar net exports decline by 2.39%, compared to 0.82% in model one.

We can see that generally ethanol market changes more dramatically relative to that of model one, so the sugar market shows the same pattern, namely change percentages of all the endogenous variables are more remarkable than those in model one.

The reason that Brazilian ethanol market changes more drastically than that in model one is that EU and Rest-of-World play significant roles on ethanol demand resulted from an increase in world crude oil price.

Table 5.7 Scenario result of U.S. for model two shock two: world crude oil price increases by 20%

	Baseline	oil price shock	absolute value of the difference	relative difference
Ethanol Production	65,704	63,392	-2,311	-3.52%
Ethanol Consumption	63,390	61,030	-2,360	-3.72%
Ethanol Net trade	-1,142	-1,236	-94	8.27%
Conv. rack	2.29	2.38	0.09	3.79%
Conv. RIN	0.71	0.47	-0.24	-33.80%
Adv. RIN	1.52	1.36	-0.16	-10.53%

Table 5.8 Scenario result of EU for model two shock two: world crude oil price increases by 20%

	Baseline	oil price shock	absolute value of the difference	relative difference
Ethanol Production	6290	6567	277	4.40%
Ethanol Consumption	7586	7928	343	4.52%
Ethanol Net trade	-1296	-1362	-66	5.09%

As for the second shock, almost 100% of world crude oil price transmits to the gasoline prices of U.S. and EU, unlike what happens in Brazil. Because of the way that the cellulosic credit is calculated, increasing world crude oil price leads to a fall in the value of cellulosic credits, thereby reducing the profitability of cellulosic ethanol. Thus, production of cellulosic ethanol decreases. Since the cellulosic ethanol mandate is by assumption set at its production, the total mandate is waived down by the shortfall in the cellulosic ethanol mandate. So the total mandate falls and so does consumption of ethanol since the mandate is binding.

In addition, the increasing gasoline price resulted from the rise in world crude oil price makes ethanol more competitive. Thus, blenders prefer to purchase ethanol rather than RIN, so there is less demand for RIN which causes RIN prices to fall. We can see that prices of both advanced ethanol RIN and conventional ethanol RIN drops, 10.53% and 33.80% respectively.

The 3.52% reduction in U.S. ethanol production, a 3.72% decline in its ethanol consumption and a 8.27% rise in its net ethanol imports indicates that the increasing world crude oil price does not lead to the significant substitution gasoline with ethanol in the U.S. Given its ambitious quantitative targets of ethanol usage set by Energy Independence and Security Act, an increase in oil price of more than 20% is required to spur this substitution. For the U.S., given the level of fuel use, ethanol and oil price, the main impact of the scenario is on RIN values.

In the EU and Rest-of-World, increasing world crude oil price makes the ethanol price more competitive, compared to gasoline price. In the EU there is some substitution between gasoline and ethanol allowed to reflect markets and that at higher prices the EU might be more likely to increase blending ratios there, if oil prices are higher. Thus, its ethanol consumption increases as well as ethanol production, 4.52% and 4.40% respectively.

Additionally, net imports of ethanol from the rest of world increase as a result of the shock of world crude oil price. Consequently, the supply side of Brazil and demand sides of U.S., EU and rest of world all make Brazilian ethanol net exports increase even more.

Chapter 6 Conclusions

Biofuels have been receiving greater attention in recent years from scholars, governments, relative industries and environmental organizations. This study is an attempt to pay special attention to the biofuel market, and the linkages between ethanol markets and agricultural markets. Specifically, the partial equilibrium modeling system is used to examine the extent to which the mandated blending ratio of Brazil and international price volatility in the energy sector are transmitted to the ethanol sector and the sugar market.

An increase in the mandated blending ratio leads to the increase of anhydrous ethanol domestic consumption, resulting in the rise in anhydrous ethanol price accordingly. Then, gasoline C price goes up. However, gasoline C domestic use goes up, rather than down. That’s because the price trigger causes a sharp fall of hydrous ethanol domestic use. Meanwhile, some consumers switch to consume gasoline C. The substitute effect dominates.

Finally, Brazilian ethanol net exports go down, making the equilibrium hydrous ethanol price increase. Therefore, total ethanol production goes up, whereas the sugar market experiences a decline in sugar production as well as sugar domestic consumption. The equilibrium world sugar price and sugar domestic price rise. For the second model, the directions of change for all the endogenous variables are the same with model one, but the magnitude is different.

An increase in world crude oil price leads to the rise in gasoline C price and decrease of its domestic use. Then, the demand for liquid biofuels is boosted as a substitute for gasoline. According to the changing patterns of hydrous ethanol domestic use, anhydrous ethanol domestic use and ethanol ending stock, the ethanol net exports follow the same pattern as ethanol ending stocks do. Consequently, equilibrium hydrous ethanol prices to producers go up dramatically during 11/12 and 18/19 to20/21, but rise less for the rest of the years.

Due to the increase in equilibrium hydrous ethanol price, ethanol production goes up. Hence, the share of sugarcane used for sugar is reduced. Also, given the directions and magnitudes of change of sugar ending stock and sugar domestic use, Brazilian sugar exports go down, thereby causing increases in the international sugar price and sugar domestic price as well.

Based on the analysis of this shock, we can conclude that higher crude oil price has played a key role in boosting biofuels, though this result depends in part on asumed elasticities of gasoline C price with respect to petroleum price. Similar to the comparison of two kinds of models of the first shock, the change directions of all variables in model two are the same with those in the first model, but the change magnitudes are different. Almost all the change percentages of variables in model two are larger than those in model one, indicating that markets outside Brazil amplify the effects of world crude oil price.

From the related discussion above, we can draw some policy implications for Brazil. It is obvious that an increase in mandated ethanol use will be beneficial to spurring ethanol production and consumption. But the extent of this incentive will depend on how close it is to that 70% level. Since according to the simulation, once the hydrous ethanol price is more than seventy percent of gasoline C price, it might just cause a switch from hydrous ethanol use to gasoline C.

Another way to stimulate ethanol industry is to eliminate the price lid on Brazilian gasoline C, allowing its price to rise. Though this may reduce gasoline C use, it also would increase hydrous ethanol use. In other words, getting rid of the price ceiling on gasoline C price results in the need for stronger hydrous ethanol demand to reach 70% price trigger.

Moreover, we saw that in 2011 the price trigger plays a crucial role on hydrous ethanol consumption, and there is a very strong response of hydrous ethanol use to relative prices of hydrous ethanol and gasoline C. In the future, the proportion of flex-fuel vehicles will rise, potentially increasing the sensitivity of the model.

All in all, this study illustrates that biofuel policies and the volatility of crude oil price not only have impacts on ethanol markets, but also affect agricultural markets. In addition, using model two, we can see the price of international ethanol price is impacted by and impacts not only Brazilian market, but also how U.S., EU and rest of the world respond to the price change. Further research would include more markets, such as fertilizer markets, by-products markets, or other substitute energy markets in this model system, allowing a more comprehensive dynamic analysis.

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Appendix

Appendix A Data names, units, and sources

Description	Name	Units	Source
Sugar domestic price	PDSUGAR	Real/kg	FAPRI-MU model dataset
World sugar price	PWSUGAR	Dollar/lb	FAPRI-MU model dataset
Anhydrous ethanol price	PANETHN	Dollar/liter	CEPEA
Hydrous ethanol price to producers	PETHNPRD	Dollar/liter	CEPEA
Hydrous ethanol price to consumers	PETHNCON	Real/liter	ANP
Dehydration cost	CDEHYDR	Dollar/liter	Calculated by using anhydrous ethanol price minus hydrous ethanol price
Gasoline C price	PGASO	Real/liter	ANP
World crude oil price	PWOROIL	Dollar/barrel	FAPRI-MU model dataset
Total fuel demand	DTOFUEL	Million liter	Calculated by adding gasoline C use to hydrous ethanol use
Energy equivalent value of total fuel demand	EEDTOFUEL	Million liter	Calculated by sum of energy equivalent value of gasoline C use and energy equivalent value of hydrous ethanol use
Brazil's GDP	BRZGDP	Real dollar	FAPRI-MU model dataset
Weighted fuel price	PWFUEL	Real/liter	Calculated by weighting gasoline C price and hydrous ethanol price
Gasoline C consumption	CGASOC	Million liter	Calculated by consumption of anhydrous ethanol and mandate blending ratio
Energy equivalent value of gasoline C use	EECGASOC	Million liter	Calculated by sum of gasoline A domestic use and anhydrous ethanol domestic use divided by 1.5
Gasoline A consumption	AGASOC	Million liter	Calculated by using gasoline C minus anhydrous ethanol use
Hydrous ethanol domestic consumption	CDOHYETH	Million liter	USDA GAIN reports, ANP, UNICA
Energy equivalent value of hydrous ethanol domestic use	EECDOHYETH	Million liter	Calculated by using hydrous ethanol domestic use divided by 1.5
Share of sugarcane demanded for ethanol	SETHANOL	%	Calculated by using one minus share of sugarcane demanded for sugar
Price trigger	PTRIGGER	-	Calculated based on FAPRI-MU model dataset
Share of FFT in total vehicles	SFFV	%	UNICA
Anhydrous ethanol domestic use	CDOANHYETH	Million liter	USDA GAIN reports, ANP, UNICA
Energy equivalent value of	EECDOANHYETH	Million liter	Calculated by using

Anhydrous ethanol domestic use			anhydrous ethanol domestic use divided by 1.5
Mandate blending ratio	RMANBLD	%	USDA report
Total ethanol production	TETHPRO	Million liter	USDA GAIN reports
Sugarcane production	SUGCANPRO	1000MT	USDA GAIN reports
Conversion factor	CONVEFA	-	Calculated by using sugarcane production divided by sugarcane used for sugar production
Total ethanol ending stock	TETHEST	Million liter	USDA GAIN reports
Brazil's ethanol net export	ETHNTEXP	Million liter	
Total ethanol beginning stock	TETHBST	Million liter	USDA GAIN reports
Sugar domestic use per capita	CSUGPER	Kg per capital	USDA Production, Supply and Distribution table
Brazilian income per capita	INCPER	Real dollar/million	FAPRI-MU model baseline
Sugar ending stock	SUGESTK	1000MT	USDA Production, Supply and Distribution table
Sugar production	SUGPRO	1000MT	USDA Production, Supply and Distribution table
Share of sugarcane demanded for sugar	SSUGAR	%	USDA GAIN reports
Sugarcane area planted	ARSUGCAN	1000HA	USDA GAIN reports
Sugarcane price	PSUGCAN	Real/kg	Consecana
Sugarcane area harvested	HARSUGCAN	1000HA	USDA GAIN reports
Sugarcane yield	YIDSUGCAN	MT/HA	Calculated by using sugarcane production divided by sugarcane area harvested
Sugar export	SUGEXP	1000MT	USDA Production, Supply and Distribution table
Sugar beginning stock	SUGBSTK	1000MT	USDA Production, Supply and Distribution table
Sugar domestic use	CONSUG	1000MT	USDA Production, Supply and Distribution table
Rest of world sugar net import from Brazil	RESSUGIMP	1000MT	FAPRI-MU model
US GDP deflator	DEFLUSG	Index	FAPRI-MU model baseline
Rest of world GDP	RESWGDP	Real dollar	FAPRI-MU model baseline
Rest of world population	RESWPOP	Million	FAPRI-MU model baseline
Rest of world net ethanol import from Brazil	RESETHIMP	Million liter	FAPRI-MU model
U.S. ethanol net import	USETHNTIMP	Million liter	FAPRI-MU model
EU ethanol net import	EUETHNTIMP	Million liter	FAPRI-MU model
Rest of world ethanol net import	RESWETHIMP	Million liter	FAPRI-MU model
U.S. sugar net import	USSUGIMP	1000MT	FAPRI-MU model
EU sugar net import	EUSUGIMP	1000MT	FAPRI-MU model
Rest of world sugar net import	RESWSUGIMP	1000MT	FAPRI-MU model

Appendix B Tables showing the baselines of two models

Baseline for model one										
	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
sugarcane area planted	9223.60	9503.27	9797.10	10050.51	10267.80	10468.18	10656.77	10837.91	11012.05	11174.12
sugarcane area harvested	8733.38	8982.17	9243.56	9468.98	9662.28	9840.54	10008.30	10169.44	10324.35	10468.52
sugarcane yield	64.52	68.81	73.38	75.00	75.69	75.84	76.06	76.35	76.64	76.79
sugarcane production	563474.11	618063.59	678318.47	710174.80	731357.15	746286.15	761187.34	776416.69	791243.51	803908.25
share of sugarcane demanded for sugar	0.48	0.48	0.47	0.47	0.46	0.46	0.45	0.45	0.45	0.44
sugarcane price	0.41	0.50	0.48	0.45	0.45	0.46	0.48	0.50	0.51	0.51
sugar production	36406.80	39779.05	43122.71	44683.54	45556.56	46033.00	46446.93	47010.39	47733.52	48356.48
sugar domestic use	12209.15	12613.80	13040.20	13430.48	13792.29	14153.99	14507.65	14871.63	15247.97	15627.43
sugar ending stock	-318.11	-223.27	-140.41	-111.87	-97.19	-93.53	-88.43	-79.33	-66.40	-58.58
sugar domestic price	1.35	1.12	0.99	0.97	0.97	1.00	1.03	1.05	1.06	1.09
sugar export	24230.76	27070.41	29999.65	31224.53	31749.59	31875.35	31934.19	32129.66	32472.61	32721.23
world sugar demand for Brazil	24230.76	27070.41	29999.65	31224.53	31749.59	31875.35	31934.19	32129.66	32472.61	32721.23
equilibrium world sugar price	0.27	0.22	0.19	0.18	0.18	0.19	0.19	0.20	0.20	0.20
total ethanol production	23209.26	25753.23	28803.23	30577.25	31883.59	32911.97	33979.97	34984.73	35857.64	36611.77
gasoline C price	2.79	3.41	3.43	3.50	3.64	3.76	3.80	3.80	3.78	3.88
weighted fuel price of gasoline C and hydrous ethanol price	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
total fuel demand	43348.71	42773.45	45163.83	47322.31	48965.92	50703.96	52614.60	54771.95	57083.84	59092.51
share of hydrous ethanol consumption in total fuel demand	0.22	0.25	0.27	0.28	0.29	0.29	0.29	0.29	0.28	0.27
gasoline C domestic use	41665.09	39709.78	40820.98	42005.19	42904.09	44038.97	45401.29	47351.99	49660.73	51522.43
hydrous ethanol domestic use	14474.67	16349.22	18379.10	19958.92	21165.88	22184.11	23142.82	23647.87	23883.47	24290.08
anhydrous ethanol domestic use	8333.02	7941.96	8164.20	8401.04	8580.82	8807.79	9080.26	9470.40	9932.15	10304.49
total ethanol ending stock	5846.69	6286.46	6952.54	7331.25	7571.02	7720.70	7871.60	8073.79	8282.86	8423.22
hydrous ethanol price to consumers	1.96	2.36	2.22	2.22	2.33	2.48	2.63	2.66	2.65	2.73
anhydrous ethanol price	0.79	0.81	0.75	0.73	0.74	0.77	0.80	0.81	0.79	0.80
Brazil's ethanol net export	1385.89	1412.96	1984.52	2229.23	2287.80	2161.05	1996.66	2054.94	2223.61	2267.50
rest of world net ethanol imports	1385.89	1412.96	1984.52	2229.23	2287.80	2161.05	1996.66	2054.94	2223.61	2267.50
equilibrium hydrous ethanol price to producers	0.67	0.68	0.63	0.61	0.62	0.65	0.67	0.68	0.66	0.67

Baseline for model two										
	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
sugarcane area planted	9223.60	9503.27	9797.10	10041.94	10252.35	10452.96	10643.82	10820.36	10993.32	11157.36
sugarcane area harvested	8733.38	8982.17	9243.56	9461.37	9648.54	9826.99	9996.78	10153.82	10307.69	10453.61
sugarcane yield	64.52	68.81	73.38	74.79	75.48	75.77	76.04	76.17	76.52	76.75
sugarcane production	563474.11	618063.59	678318.47	707626.16	728282.35	744558.13	760109.84	773428.82	788772.46	802293.47
share of sugarcane demanded for sugar	0.48	0.47	0.46	0.45	0.45	0.44	0.43	0.43	0.43	0.43
sugarcane price	0.41	0.50	0.46	0.42	0.44	0.45	0.46	0.49	0.51	0.51
sugar production	36406.80	38772.63	42011.00	43080.03	43812.08	44304.15	44705.04	45122.50	45857.19	46555.87
sugar domestic use	12209.15	12693.46	13069.37	13457.69	13806.44	14182.00	14529.59	14886.12	15260.45	15638.79
sugar ending stock	-318.11	-182.13	-133.03	-110.67	-105.57	-92.75	-91.73	-88.94	-77.22	-69.39
sugar domestic price	1.35	0.93	0.92	0.90	0.93	0.92	0.97	1.01	1.03	1.06
sugar export	24230.76	25943.18	28892.53	29599.98	30000.53	30109.33	30174.43	30233.58	30585.02	30909.24
world sugar demand for Brazil	24230.76	25943.18	28892.54	29599.98	30000.53	30109.33	30174.43	30233.58	30585.02	30909.25
equilibrium world sugar price	0.27	0.18	0.18	0.17	0.18	0.18	0.18	0.19	0.19	0.19
total ethanol production	23209.26	26383.74	29500.00	31366.95	32717.32	33850.34	34982.11	35916.46	36826.32	37606.12
gasoline C price	2.79	3.43	3.39	3.50	3.65	3.72	3.78	3.80	3.78	3.88
weighted fuel price of gasoline C and hydrous ethanol price	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
total fuel demand	43348.71	42665.22	45396.48	47289.67	48914.14	50883.17	52707.91	54760.29	57033.57	59110.62
share of hydrous ethanol consumption in total fuel demand	0.22	0.25	0.27	0.28	0.29	0.29	0.29	0.29	0.27	0.28
gasoline C domestic use	41665.09	39849.42	40866.64	42000.17	42897.32	44056.89	45407.77	47482.40	50279.54	51288.74
hydrous ethanol domestic use	14474.67	15991.37	18664.15	19916.98	21097.69	22427.84	23273.72	23447.80	22941.73	24644.43
anhydrous ethanol domestic use	8333.02	7969.88	8173.33	8400.03	8579.46	8811.38	9081.55	9496.48	10055.91	10257.75
total ethanol ending stock	5846.69	6352.42	7124.95	7439.50	7680.95	7908.08	8045.43	8211.75	8423.90	8572.37
hydrous ethanol price to consumers	1.96	2.40	2.13	2.24	2.35	2.41	2.58	2.67	2.66	2.72
anhydrous ethanol price	0.79	0.82	0.72	0.74	0.75	0.75	0.79	0.81	0.79	0.80
Brazil's ethanol net export	1385.89	2307.42	2280.67	3126.05	3189.39	2774.67	2880.14	3196.53	4007.19	2946.14
rest of world net ethanol imports	1385.89	2307.46	2280.85	3126.12	3189.39	2774.71	2880.35	3196.55	4007.21	2946.16
equilibrium hydrous ethanol price to producers	0.67	0.69	0.60	0.62	0.62	0.62	0.66	0.68	0.67	0.67

Appendix C Tables showing the absolute values of scenarios results

Absolute value of scenario result of model one shock one: setting mandate blending ratio to 30%

	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
sugarcane area planted	9223.60	9503.27	9799.82	10057.30	10291.76	10509.37	10710.24	10894.91	11063.51	11218.25
sugarcane area harvested	8733.38	8982.17	9245.98	9475.03	9683.60	9877.18	10055.87	10220.14	10370.12	10507.78
sugarcane yield	64.52	68.81	73.45	75.11	76.14	76.38	76.56	76.70	76.79	76.87
sugarcane production	563474.11	618063.59	679108.38	711699.18	737356.07	754393.55	769878.54	783881.26	796285.84	807728.15
share of sugarcane demanded for sugar	0.48	0.48	0.46	0.46	0.45	0.44	0.44	0.44	0.44	0.44
sugarcane price	0.41	0.51	0.49	0.49	0.51	0.52	0.52	0.52	0.52	0.52
sugar production	36324.70	39601.64	42550.48	43759.57	44595.46	45168.99	45837.43	46582.89	47367.23	48054.66
sugar domestic use	12205.92	12607.74	13019.27	13400.36	13764.08	14129.52	14492.07	14860.32	15237.73	15619.32
sugar ending stock	-320.92	-228.93	-159.40	-140.19	-124.87	-117.95	-104.54	-90.85	-76.59	-66.74
sugar domestic price	1.36	1.13	1.04	1.05	1.04	1.06	1.07	1.08	1.09	1.12
sugar export	24154.70	26901.92	29461.68	30340.00	30816.07	31032.55	31331.94	31708.89	32115.24	32425.49
world sugar demand for Brazil	24154.70	26901.92	29461.68	30340.00	30816.07	31032.55	31331.94	31708.89	32115.24	32425.49
equilibrium world sugar price	0.27	0.22	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.21
total ethanol production	23260.68	25864.38	29228.67	31285.66	32994.94	34142.17	35101.02	35888.16	36517.20	37127.18
gasoline C price	2.81	3.44	3.57	3.65	3.79	3.86	3.84	3.82	3.79	3.90
weighted fuel price of gasoline C and hydrous ethanol price	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
total fuel demand	42960.62	42274.29	44232.08	46315.25	48019.69	49995.19	52209.06	54465.04	56771.44	58770.51
share of hydrous ethanol consumption in total fuel demand	0.14	0.18	0.22	0.24	0.25	0.25	0.24	0.22	0.21	0.20
gasoline C domestic use	46622.60	44112.03	43815.24	44835.05	45684.90	47476.41	49875.84	52481.76	55309.04	57571.24
hydrous ethanol domestic use	9005.19	11364.96	14702.31	16450.33	17859.69	18404.41	18485.99	18351.96	17994.72	17939.37
anhydrous ethanol domestic use	13986.78	13233.61	13144.57	13450.52	13705.47	14242.92	14962.75	15744.53	16592.71	17271.37
total ethanol ending stock	5820.20	6246.51	6789.69	7188.04	7510.58	7757.46	7987.93	8188.59	8361.12	8479.59
hydrous ethanol price to consumers	1.99	2.43	2.51	2.57	2.66	2.72	2.71	2.70	2.69	2.77
anhydrous ethanol price	0.81	0.83	0.85	0.85	0.85	0.84	0.83	0.82	0.80	0.82
Brazil's ethanol net export	1279.51	1230.16	1229.27	1377.13	1497.91	1638.63	1812.48	1981.68	2147.90	2188.64
rest of world net ethanol imports	1279.51	1230.16	1229.27	1377.13	1497.91	1638.63	1812.48	1981.68	2147.90	2188.64
equilibrium hydrous ethanol price to producers	0.68	0.70	0.72	0.71	0.71	0.71	0.70	0.69	0.67	0.68

Absolute value of scenario result of model one shock two: a 20% rise in world crude oil price										
	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
sugarcane area planted	9223.60	9503.27	9810.18	10063.22	10276.90	10475.94	10664.20	10845.26	11019.51	11186.69
sugarcane area harvested	8733.38	8982.17	9255.20	9480.29	9670.38	9847.43	10014.91	10175.98	10330.98	10479.71
sugarcane yield	64.52	68.81	73.70	75.06	75.67	75.85	76.09	76.38	76.68	76.95
sugarcane production	563474.11	618063.59	682127.54	711557.05	731729.85	746931.81	761997.63	777270.91	792156.68	806461.21
share of sugarcane demanded for sugar	0.47	0.47	0.47	0.46	0.46	0.45	0.45	0.44	0.44	0.44
sugarcane price	0.41	0.53	0.48	0.44	0.45	0.46	0.48	0.51	0.53	0.55
sugar production	36026.11	39460.85	43094.46	44594.63	45437.34	45934.83	46353.44	46766.31	47203.00	47700.12
sugar domestic use	12194.15	12605.89	13041.50	13426.52	13788.87	14151.28	14504.94	14863.26	15230.66	15608.25
sugar ending stock	-331.13	-231.53	-139.87	-115.27	-100.57	-96.26	-91.11	-87.13	-82.73	-77.29
sugar domestic price	1.39	1.14	0.99	0.98	0.98	1.01	1.04	1.07	1.11	1.15
sugar export	23878.09	26755.36	29961.30	31143.51	31633.77	31779.25	31843.35	31899.07	31967.93	32086.43
world sugar demand for Brazil	23878.09	26755.36	29961.30	31143.51	31633.77	31779.25	31843.35	31899.07	31967.93	32086.43
equilibrium world sugar price	0.28	0.22	0.19	0.19	0.19	0.19	0.20	0.20	0.21	0.21
total ethanol production	23447.66	25952.58	29143.01	30750.02	31989.97	33028.37	34107.51	35210.71	36268.78	37242.07
gasoline C price	3.08	3.68	3.70	3.77	3.93	4.05	4.09	4.13	4.15	4.26
weighted fuel price of gasoline C and hydrous ethanol price	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
total fuel demand	42284.79	41921.60	44435.08	46589.68	48209.18	49963.15	51913.00	53936.52	56074.26	58091.95
share of hydrous ethanol consumption in total fuel demand	0.24	0.26	0.28	0.29	0.29	0.30	0.30	0.30	0.30	0.29
gasoline C domestic use	39765.32	38721.66	39883.20	41086.71	41987.12	43131.52	44517.56	46003.78	47726.49	49477.18
hydrous ethanol domestic use	15538.48	16454.79	18598.87	20145.86	21314.53	22343.32	23327.65	24282.21	25077.03	25652.61
anhydrous ethanol domestic use	7953.06	7744.33	7976.64	8217.34	8397.42	8626.30	8903.51	9200.76	9545.30	9895.44
total ethanol ending stock	5716.51	6298.21	7016.00	7357.54	7576.32	7724.09	7874.49	8036.11	8208.49	8384.17
hydrous ethanol price to consumers	2.12	2.39	2.20	2.22	2.34	2.51	2.65	2.79	2.90	2.99
anhydrous ethanol price	0.86	0.82	0.75	0.73	0.74	0.78	0.81	0.84	0.87	0.88
Brazil's ethanol net export	1070.60	1562.43	2240.38	2435.95	2449.91	2301.64	2116.61	1956.79	1864.75	1909.01
rest of world net ethanol imports	1070.60	1562.43	2240.38	2435.95	2449.91	2301.64	2116.61	1956.79	1864.75	1909.01
equilibrium hydrous ethanol price to producers	0.72	0.68	0.63	0.61	0.62	0.65	0.68	0.71	0.73	0.74

Absolute value of scenario result of model two shock one: setting mandate blending ratio to 30%										
	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
sugarcane area planted	9223.60	9503.27	9799.82	10046.74	10278.66	10493.67	10694.34	10878.38	11047.40	11203.17
sugarcane area harvested	8733.38	8982.17	9245.98	9465.63	9671.95	9863.21	10041.72	10205.44	10355.79	10494.37
sugarcane yield	64.52	68.81	73.45	74.86	76.03	76.25	76.48	76.61	76.71	76.81
sugarcane production	563474.11	618063.59	679108.38	708554.46	735359.80	752057.29	767961.82	781791.17	794442.00	806122.56
share of sugarcane demanded for sugar	0.48	0.46	0.45	0.44	0.43	0.43	0.42	0.42	0.42	0.42
sugarcane price	0.41	0.51	0.46	0.48	0.49	0.51	0.51	0.51	0.51	0.52
sugar production	36324.70	38666.90	41361.41	42076.61	42900.70	43332.39	43960.74	44666.64	45477.61	46228.74
sugar domestic use	12205.92	12689.31	13047.62	13434.99	13784.30	14153.20	14511.12	14876.18	15250.40	15630.53
sugar ending stock	-320.92	-185.85	-153.31	-135.08	-128.87	-121.05	-111.06	-99.86	-87.41	-77.90
sugar domestic price	1.36	0.94	0.97	0.96	0.99	1.00	1.02	1.04	1.06	1.08
sugar export	24154.70	25842.52	28281.24	28623.39	29110.19	29171.37	29439.63	29779.26	30214.75	30588.70
world sugar demand for Brazil	24154.70	25842.52	28281.24	28623.39	29110.19	29171.37	29439.63	29779.26	30214.75	30588.70
equilibrium world sugar price	0.27	0.18	0.19	0.18	0.19	0.19	0.19	0.19	0.20	0.20
total ethanol production	23260.68	26449.98	29973.93	32074.72	33888.89	35096.55	36116.49	36914.06	37547.65	38138.23
gasoline C price	2.81	3.44	3.56	3.65	3.78	3.85	3.84	3.82	3.79	3.89
weighted fuel price of gasoline C and hydrous ethanol price	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
total fuel demand	42960.62	42245.91	44422.50	46457.02	48165.98	50150.93	52300.91	54501.09	56778.88	58819.05
share of hydrous ethanol consumption in total fuel demand	0.14	0.17	0.26	0.26	0.27	0.27	0.25	0.23	0.21	0.21
gasoline C domestic use	46622.60	44330.45	42280.78	43609.55	44369.27	45977.87	48899.22	52058.41	55212.55	56911.06
hydrous ethanol domestic use	9005.19	11027.53	17059.47	18317.41	19855.23	20661.04	19942.19	18977.57	18136.16	18903.43
anhydrous ethanol domestic use	13986.78	13299.14	12684.23	13082.87	13310.78	13793.36	14669.77	15617.52	16563.76	17073.32
total ethanol ending stock	5820.20	6331.57	6914.32	7315.38	7653.46	7909.72	8145.08	8343.65	8514.99	8633.21
hydrous ethanol price to consumers	1.99	2.44	2.49	2.56	2.65	2.70	2.70	2.70	2.69	2.76
anhydrous ethanol price	0.81	0.83	0.85	0.84	0.84	0.84	0.83	0.81	0.80	0.81
Brazil's ethanol net export	1279.51	2002.61	38.14	664.06	775.47	776.55	1659.84	2511.08	3067.04	2433.93
rest of world net ethanol imports	1279.51	2002.61	38.14	664.06	775.47	776.55	1659.84	2511.08	3067.05	2433.94
equilibrium hydrous ethanol price to producers	0.68	0.70	0.71	0.71	0.71	0.70	0.69	0.68	0.67	0.68

Absolute value of scenario result of model two shock two: a 20% rise in world crude oil price

	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
sugarcane area planted	9223.60	9503.27	9797.10	10045.88	10258.67	10460.82	10654.29	10834.79	11008.89	11178.38
sugarcane area harvested	8733.38	8982.17	9243.56	9464.86	9654.16	9833.99	10006.09	10166.66	10321.54	10472.31
sugarcane yield	64.52	68.81	73.38	74.89	75.56	75.84	76.14	76.32	76.62	76.96
sugarcane production	563474.11	618063.59	678318.47	708796.17	729459.75	745768.01	761843.42	775918.43	790860.48	805928.87
share of sugarcane demanded for sugar	0.48	0.46	0.46	0.45	0.44	0.44	0.43	0.43	0.42	0.42
sugarcane price	0.41	0.50	0.47	0.43	0.45	0.47	0.48	0.50	0.53	0.55
sugar production	36406.80	38687.37	41848.83	42937.96	43610.65	44021.76	44439.71	44750.79	45249.94	45855.36
sugar domestic use	12209.15	12689.87	13065.60	13454.38	13800.58	14173.12	14522.98	14875.04	15242.50	15619.75
sugar ending stock	-318.11	-185.29	-137.04	-114.19	-111.34	-101.31	-98.63	-99.75	-94.72	-88.46
sugar domestic price	1.35	0.94	0.93	0.91	0.95	0.95	0.99	1.04	1.08	1.12
sugar export	24230.76	25864.68	28734.98	29460.73	29807.22	29838.61	29914.05	29876.86	30002.42	30229.34
world sugar demand for Brazil	24230.76	25864.68	28734.98	29460.73	29807.22	29838.61	29914.05	29876.86	30002.42	30229.34
equilibrium world sugar price	0.27	0.18	0.18	0.17	0.18	0.18	0.19	0.20	0.20	0.20
total ethanol production	23209.26	26437.15	29601.65	31555.08	32943.47	34130.23	35295.97	36361.70	37385.73	38356.46
gasoline C price	2.79	3.72	3.69	3.80	3.96	4.05	4.09	4.14	4.15	4.26
weighted fuel price of gasoline C and hydrous ethanol price	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
total fuel demand	43348.71	41719.20	44494.68	46438.33	48026.61	49950.41	51909.82	53853.62	56079.93	58135.18
share of hydrous ethanol consumption in total fuel demand	0.22	0.26	0.28	0.29	0.29	0.30	0.30	0.30	0.30	0.30
gasoline C domestic use	41665.09	38657.52	39897.29	41057.01	41954.95	43129.63	44517.19	45997.02	47665.01	48985.76
hydrous ethanol domestic use	14474.67	16240.99	18668.53	19960.41	21085.70	22326.87	23323.39	24167.33	25171.61	26405.43
anhydrous ethanol domestic use	8333.02	7731.50	7979.46	8211.40	8390.99	8625.93	8903.44	9199.40	9533.00	9797.15
total ethanol ending stock	5846.69	6309.28	7101.61	7434.85	7668.93	7884.76	8050.57	8185.94	8375.11	8552.70
hydrous ethanol price to consumers	1.96	2.46	2.18	2.28	2.42	2.51	2.65	2.83	2.90	2.98
anhydrous ethanol price	0.79	0.84	0.74	0.75	0.77	0.78	0.81	0.86	0.87	0.88
Brazil's ethanol net export	1385.89	2392.73	2551.99	3440.70	3623.37	3352.27	3294.00	3250.26	2882.62	2366.95
rest of world net ethanol imports	1385.89	2392.74	2551.99	3440.71	3623.37	3352.27	3294.00	3250.26	2882.62	2366.95
equilibrium hydrous ethanol price to producers	0.67	0.71	0.62	0.63	0.64	0.65	0.68	0.72	0.73	0.74

Baseline of U.S. for model two									
	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
Ethanol Production	50099.44	56753.81	60682.83	61930.14	66264.46	69822.91	73275.17	76045.69	76459.64
Ethanol Consumption	48605.77	53773.12	58880.65	60128.32	63600.08	67249.11	70789.93	74086.92	73393.92
Ethanol Net trade	-1046.72	-730.65	-1297.41	-1356.72	-792.45	-1279.68	-1456.85	-1748.93	-567.71
Conv. rack	2.56	2.13	2.27	2.26	2.22	2.26	2.29	2.30	2.32
Conv. RIN	0.14	0.64	0.90	0.73	0.82	0.70	0.88	0.66	0.89
Adv. RIN	0.94	1.09	1.67	1.55	1.58	1.67	1.89	1.62	1.69

Baseline of EU for model two									
	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
Ethanol Production	5833.73	5862.25	6129.48	6271.84	6346.58	6452.38	6472.95	6526.34	6713.42
Ethanol Consumption	6556.06	6855.52	7061.16	7329.55	7624.73	7833.64	8056.49	8330.74	8622.73
Ethanol Net trade	-722.33	-993.27	-931.67	-1057.71	-1278.15	-1381.26	-1583.54	-1804.39	-1909.31

Absolute value of U.S. for model two shock one: setting mandate blending ratio to 30%									
	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
Ethanol Production	50265.30	58349.97	62226.76	65287.10	69346.85	72316.24	73854.48	76017.69	76366.64
Ethanol Consumption	48530.07	53769.41	58531.20	61467.85	65133.50	68688.36	70810.12	73202.88	72856.47
Ethanol Net trade	-936.25	-311.23	-168.49	-107.66	34.34	-603.64	-1029.29	-1101.66	-379.60
Conv. rack	2.58	2.27	2.44	2.43	2.36	2.29	2.27	2.27	2.29
Conv. RIN	0.14	0.79	1.08	0.96	1.00	0.69	0.80	0.72	0.74
Adv. RIN	0.96	1.27	1.93	1.80	1.67	1.67	1.81	1.67	1.61

Absolute value of EU for model two shock one: setting mandate blending ratio to 30%									
	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
Ethanol Production	5854.91	6073.91	6285.60	6394.83	6447.73	6483.43	6485.87	6575.80	6770.63
Ethanol Consumption	6537.92	6675.07	6902.82	7185.31	7489.54	7781.00	8046.76	8339.11	8632.91
Ethanol Net trade	-683.01	-601.16	-617.22	-790.48	-1041.81	-1297.58	-1560.89	-1763.31	-1862.29

Absolute value of U.S. for model two shock two: world crude oil price increases by 20%									
	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
Ethanol Production	50751.23	57167.05	60001.44	62039.07	63258.50	65157.22	68288.45	71006.48	72862.08
Ethanol Consumption	49100.65	54244.01	58311.99	60454.26	61179.37	62848.70	65811.49	68020.31	69295.07
Ethanol Net trade	-945.87	-736.39	-1684.48	-1645.68	-1269.48	-1538.15	-1746.54	-1136.90	-424.03
Conv. rack	2.63	2.20	2.24	2.33	2.33	2.32	2.39	2.45	2.52
Conv. RIN	0.12	0.46	0.52	0.50	0.48	0.48	0.49	0.60	0.55
Adv. RIN	0.91	0.84	1.44	1.38	1.35	1.54	1.68	1.66	1.46

Absolute value of EU for model two shock two: world crude oil price increases by 20%									
	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
Ethanol Production	6089.83	6115.66	6341.08	6469.26	6540.20	6612.99	6725.88	6938.31	7266.71
Ethanol Consumption	6947.83	7246.11	7422.11	7659.28	7925.15	8134.37	8346.85	8656.28	9016.87
Ethanol Net trade	-858.00	-1130.45	-1081.03	-1190.02	-1384.95	-1521.38	-1620.97	-1717.97	-1750.16