FROM FOSSIL FUELS TO RENEWABEL ENERGY: THE DYNAMICS OF REPLACEMENT IN BRAZIL

Joaquim Rocha dos Santos, M.Eng.
Escola Politécnica da Universidade de São Paulo
jrsantos@usp.br

Marcelo Ramos Martins, PhD.
Escola Politécnica da Universidade de São Paulo
mrmartin@usp.br

ABSTRACT

The widespread replacement of fossil fuel for biofuels led to a discussion on its potential side effects in many areas. Despite the consequences of biofuels are still in discussion and that seems it will take time to came to an agreement, some authors suggest biofuels should be taxed so as to guarantee food safety as well as for other reasons. Others suggest biofuels should be banished. Some biofuels programs depend strongly on government subsidies, but some not. Brazilian ethanol seems to have reached independence on government subsidies and is now an economic activity in Brazil. The maturity of this independence has been achieved due a new technology – the flex fuel electronic injection. But before this new technology the ethanol program suffered from a severe decline of demand, with relevant economic and social consequences. This paper explores the dynamics of the period of growth, stabilization and decline of the PROALCOOL program in Brazil, in order to generate insights to support public politics as well as to contribute to academic community discussions. (1970 to 2002). Multiple information sources were used to structure a theory to explain the dynamics of a period of growth followed by a decline of usage of ethanol in Brazil. Results permit to conclude that a sudden change in politics actions, charging biofuels can lead to a fuel shortage and some relevant social and economic consequences. Next steps to this work would be to investigate the dynamics of the replacement after the insertion of the flex fuel technology (2003), to investigate the consequences of the growth of biofuels production. These consequences spread to food security, environmental impacts, economics, deforestation and others.

Introduction

In 2008, the use of ethanol as a fuel was around 2% of the Gasoline consumption. (Goldemberg and Guardabassi 2009). In 2006, roughly 45 billion liters of ethanol were produced in the world. Two countries produced three quarters of this amount: United States, that produces ethanol from maize; and Brazil, that produces ethanol from sugarcane (Goldemberg 2007). Each country contributed approximately with half of these three quarters.

One relevant advantage of ethanol is that it does not have some impurities found in oil products, such as: sulphur, oxides and particulates. The absence of these impurities is due to the manufacturing process and its raw material, sugarcane. These characteristics may conclude that ethanol is a good alternative do gasoline (Moreira e Goldemberg 1999).

Considering the whole supply chain, when proper feedstock and agricultural practices are used, it has been demonstrated that ethanol reduced greenhouse gas emissions (Goldemberg 2007).

The use of biofuels is controversial. Despite its strategic and economic advantages, some relevant objections have been raised regarding its use. Perhaps the most impacting objection was raised by Ziegler reporteur in the General Assembly of the United Nations in 2007. Ziegler raised the issue of the ‘’potentially grave negative impacts of biofuels (or agro fuels) on the right to food and the serious risk of creating a battle between food and fuel’’. (Ziegler 2007)

In 2007 the Swiss Government published a study conducted with the purpose of supporting the Government decision on subsidies. This study came to a conclusion that ethanol from sugarcane reduce greenhouse gases emissions, but has greater impact when considering the aggregated environmental impacts (Zah, et al. 2007).

Laurence (2007) pointed out a possible ‘’corn connection’’, linking ethanol production from maize in the United States to Amazonia deforestation. A study conducted in Brazil Institute for International Trade Negotiation (ICONE) developed the Brazilian Land Use Model (BLUM)[1].

The Sugarcane Industry Association (UNICA)[2] points out that:

> *The South-Central Brazil is the heart of the country’s sugarcane industry. Areas marked in red on the above map indicate where sugarcane is harvested and sugar, ethanol and bioelectricity plants are located. Data supplied by the Brazilian Institute of Geography and Statistics (IBGE), the University of Campinas (UNICAMP) and the Center for Sugarcane Technology (CTC).*

Based on these sources, UNICA (2011) presents in its website the Map reproduced in Figure 1. Data on sugarcane, sugar and ethanol production in different harvest seasons are available on UNICA’s quotes and statistics page[3].

---

[1] A partial view and report f the BLUM can be seen in ICONE site, at: http://www.iconebrasil.org.br/en/. Informations in English are available.

[2] ÚNICA – União das Indústrias da Cana-de-Açúcar.

[3] Informations available at http://english.unica.com.br/dadosCotacao/estatistica/

Scharlemann and Laurence (2008) argued that, on a complete life-cycle basis, biofuels might have greater aggregate environmental costs than gasoline. Perhaps the most important reference of this paper was the study conducted by Zah and others in Switzerland.

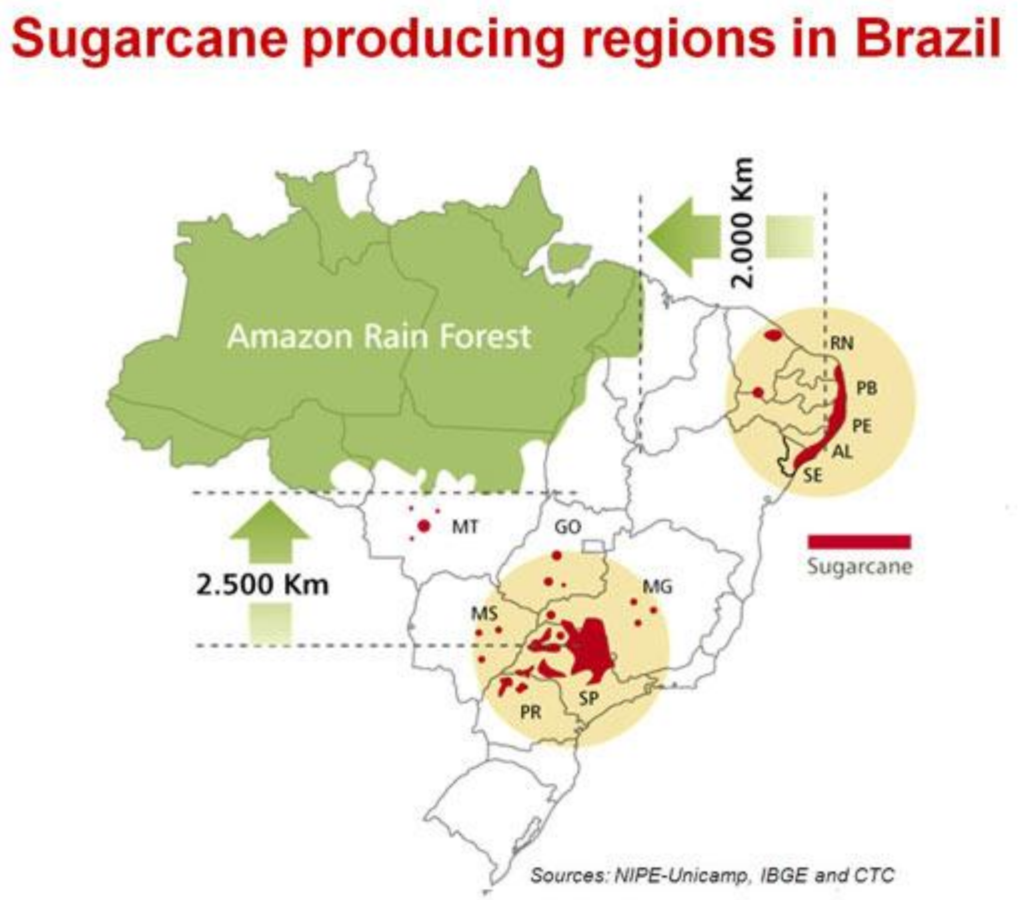

Figure 1 - Sugarcane Producing Regions in Brazil

Fonte: UNICA (2011), apud.

Fargione et al.(2008) and Searchinger et al.(2008), using a worldwide agricultural model to estimate emissions from land use, calculated that, as a result of the expansion of the ethanol production from maize in the United States, some 100,000km2 of additional land would have to come into cultivation in Brazil, China and India, leading to massive deforestation.

Sandvik (2008) and Sandvik and Moxnes (2009) used a System Dynamics model to study how markets for oil, biofuel and food may interact and develop in the long run as petroleum production declines. They came to a conclusion that “A number of proposed policies turn out to delay rather than cure the problem. A better policy is to develop alternative energy sources that do not require agricultural land. In addition one should consider building support for a ban on biofuel production requiring such land.”

Using a system dynamics model to support author’s mental models, this paper explores the consequences of some experts: a drastic reduction in biofuels usage. Brazilian ethanol offers a natural experiment. It had a period of growth, which took place from 1979 to 1986, and a period of decline, from 1987 to 2000. This period will be explored and some simulations will be run so as to foresee what might happen if experts' suggestions would be implemented.

This paper is organized in nine sections. The first section is this Introduction. Second section introduces the Sugarcane Industry in Brazil; section two has the objective to familiarize the reader with the sugarcane industry, from the Sugarcane Industry Association (UNICA)[4] perspective. The historical perspective of the sugarcane is presented from its beginning, in the XVI Century, to nowadays.

Section three presents the National Alcohol Program (Proalcool)[5]. It starts with the first oil crisis and its consequences, continues with the government decision and it strategy to leverage the program, the lack of interest due to retraction of international oil prices and Brazilian economic problems, and show the consequences of the late the eights ethanol shortage.

Section four introduces the Dynamic Hypothesis. It starts with the Model Boundary Diagram, continues with the Subsystem Diagram, and finishes with the Causal Loop Diagram, which is presented in detail.

Section five presents the Simulation Model with its eleven views (model sectors): Fleet Sector; Sugarcane and Inventory Sector; Sugarcane Capacity Utilization Sector; Sugarcane Production Capacity Sector; Desired Capital Sector; Demand Sector; Sugarcane Demand Forecast Sector; Production Schedule Sector; Effect of Scarcity Sector; Auxiliary Sector and Reference Mode Sector.

Section six presents the results. First model behavior is compared with actual data available; and second model is explored so as to investigate what would happen if ethanol were banned; this simulation is carried out through an abrupt decrease in ethanol demand.

Section seven presents the conclusions raising comments that a policy of drastic reduction of biofuels usage should be considered very carefully. Last sections of the paper are Acknowledgments and References.

Sugarcane Industry in Brazil

The Economic Cycle

In 1500, sugar was worth almost as much as gold throughout Europe. Its production was very limited and supply could not meet demand. Sugarcane crops were very profitable and coveted. Due to inadequate climate conditions, Europe could not produce it. Portugal was among the most skilled sailors at that period and ventured out in search of new lands to explore. One of their objectives was to plant sugarcane in newly discovered areas in order to produce sugar. Officially, Portugal discovered Brazil in 1500 and sugar cultivation began in 1532, after the first expedition of Martim Afonso de Souza (Sugarcane Industry Association 2011).

---

[4] UNICA – União das Indústrias da Cana-de-Açúcar.

[5] Proalcool – Programa Nacional do Álcool.

Brazil owes its first economic cycle (known as sugarcane cycle) to sugarcane. With adequate climate and land, with slave labourers from Africa, the sugarcane crops expanded and the Portuguese conquerors were very rich. Similar initiatives were carried out by other explorers in Central America (Sugarcane Industry Association 2011).

The first productive region was in the North-East of Brazil. In the course of time sugarcane spread to areas in South-East. Despite the greater distance from Europe, south-eastern cultivation was the first to earn profits. A historical curiosity: "Engenho[6] dos Erasmos", established in 1532 in the Serra do Mar mountain range was the forerunner of what today is the heart of the Brazilian sugarcane industry (Sugarcane Industry Association 2011).

Sugar mills were run like sugar factories. Standard infrastructure included the "Big House", where the Lord and his family lived; the Chapel, for religious celebrations, the "Senzala", where slaves were kept; and the mill itself, composed of different structures dedicated to various phases of sugar production (Sugarcane Industry Association 2011).

According to UNICA:

> *"Sugar production began with the crushing of the sugarcane, either in cylinders powered by water wheels or pulled by oxen. The resulting juice was transferred to furnaces to be concentrated in copper containers and then transferred to moulds for the sugar to crystallize. The next step was to purify and divide the substance into sugar loaves – the manner in which sugar was sold in Brazil. For export purposes, the loaves were crushed and dried in the sun and then packaged in boxes before being shipped to Europe"*

By the 1800s sugar industry in Brazil declined from the first to eighth position in the word production rank, with only 8% of world production. Other economic cycles came after the sugar, with special emphasis on the "Coffee Cycle" that lasts until the 20th Century. With the end of "Coffee Cycle", there was a resumption of sugarcane cultivation to produce sugar for the internal market. The states of São Paulo and Rio de Janeiro became the main suppliers, with the decline of the sector in the Northeast (Sugarcane Industry Association 2011).

In 1933 the Sugar and Alcohol Institute (IAA) was created by the Federal Government with the objective to control the sugar commodities cycles and keep prices steady. A strict quota system was introduced and mill could only produce within its pre-established quota (Sugarcane Industry Association 2011).

The attempts to ensure the competitiveness of Brazilian sugar proved to be not effective and the first oil crises in 1973 served as the opportunity to sugar producers to regain competitiveness producing fuel alcohol, or ethanol.

According to UNICA (2011):

> *In 1975, the Brazilian government launched its National Alcohol Program, known as Proálcool, which diversified the output of the sugar industry. Significant investments were made, with support from the World Bank, to allow for the expansion of areas cultivated with sugarcane and the introduction of ethanol distilleries.*

---

[6] Sugar mills

Proalcool contributed to reduce Brazil's vulnerability and increase energy security. Engineering advances following the second global oil crisis, in 1979, led to the development of engines powered strictly with hydrated ethanol (E100). By 1984, automobiles equipped with "alcohol engines" accounted for 94.4% of overall production by major automakers established in Brazil (Leite 2007).

According to UNICA:

> *After 1986, the lessened effects of the oil crisis combined with government economic plans designed to fight high inflation to cause a downward slide in the production of strictly ethanol-powered automobiles. This led to an ethanol supply crisis in 1989, and a plunge in the production of ethanol-powered vehicles, which fell to about 1% of all vehicles on the road by 2001.*

Since the Brazil's light vehicle fleet expanded, the decline of demand for hydrated ethanol (E100) was compensated by an increase in the use of anhydrous ethanol mixed with gasoline. In 25 years of large scale use of ethanol, Brazil had developed engine technologies and distribution logistics that were unprecedented in the world. The network of fueling stations where pure ethanol could be purchased achieved 28 thousand gas stations (Sugarcane Industry Association 2011).

Flex-Fuel vehicles were introduced in March of 2003. A flex-fuel car can run on ethanol, gasoline or any mixture of the two. This new technology can identify the fuel mixture in the tank at any given time, and adjust engine performance accordingly. The innovation led to a new wave of growth in the sugarcane industry, which was helped along by concerns surrounding the availability and cost of fossil fuels and growing fears about the environment and global warming. All of these combined; make ethanol an increasingly viable and important renewable fuel alternative (Sugarcane Industry Association 2011).

As of late 2007, sugarcane fields occupied about 7.8 million hectares in Brazil, or about 2% of all arable lands available in the country (Goldemberg 2007). This makes Brazil the number one producer of sugarcane in the world. Main production region (see Figure 1) are South-Central Brazil (90%), and the Northeast (10%). There are two harvests per year, which allows Brazil to produce sugar and ethanol year round for both the internal market and for export (Sugarcane Industry Association 2011).

With the end of government involvement in the sector in the late 1990s, free market rules, without subsidies. Sugar and ethanol prices have since been set according to market laws (supply and demand variations), while sugarcane prices became hinged on quality and percentage share in the finished products. To properly manage and balance both production and demands from within the sector, the industry has sought to create market instruments, such as futures trading, while developing new opportunities for both sugar and ethanol.

Ethanol Program

Due to politic reasons, in 1973, the Organization of the Petroleum Exporting Countries (OPEC) reduced dramatically the supply of oil. This reduction led to a worldwide energy and economic crisis affecting most the industrialized countries. Since the price-elasticity of demand in the short-term, no effective counteractions could take place. In fact the world deeply submerged in a recession.

The effects of this crisis in Brazil were relevant. Short term actions were carried out, with little effect, as in other countries. In the long term two strategic actions were started: the investment in petroleum exploration and production, which eventually made Brazil self sufficient in Petroleum; and the development of a biofuel program. The biofuel program (knowm as Proalcool) had two goals: the first was the development in large scale of ethanol as a fuel; and the other, more ambitious, was the development, in country, of a fully ethanol powered car, the E100.

The program included: government subsidies to ethanol producers, so as to make the fuel industrialization profitable; tax reductions or exemptions for E100 cars; and some financial incentives to increase the production capacity. Ethanol production costs were rigidly controlled by an independent institution and the program is now considered to be a success. Figure 2 shows the cars sold in Brazil from 1975 to 2007. It can be observed that during the eights E100 dominated the market in Brazil.

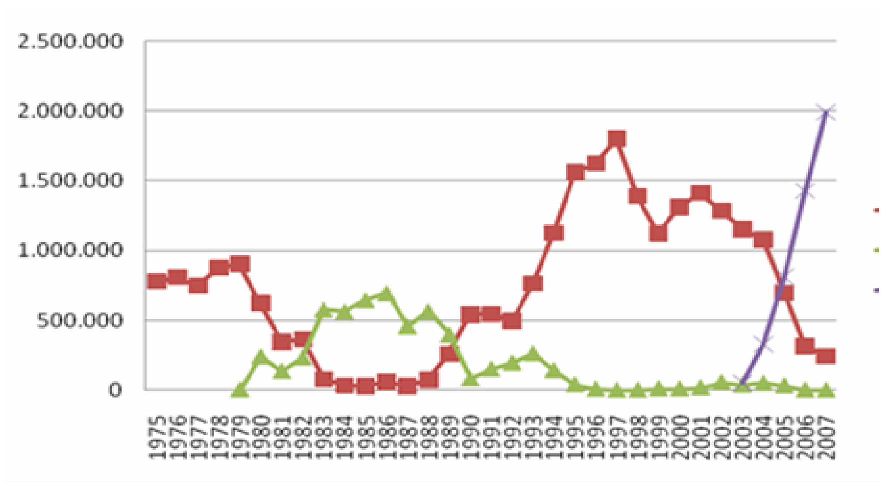

Figure 2 - Cars sold in Brazil from 1975 to 2007

Source: (Leite 2007)

The oil prices pressure decreased during the second half of the 1980, and Brazilian economy suffered due to a high inflation and macroeconomic unbalance. This led to a gradual deactivation of Proalcool program by removing some subsidies, such as those to stimulate ethanol production. Simultaneously, the international sugar prices were very attractive during that period, and sugarcane producers change the greatest part of its production to sugar, instead of ethanol.

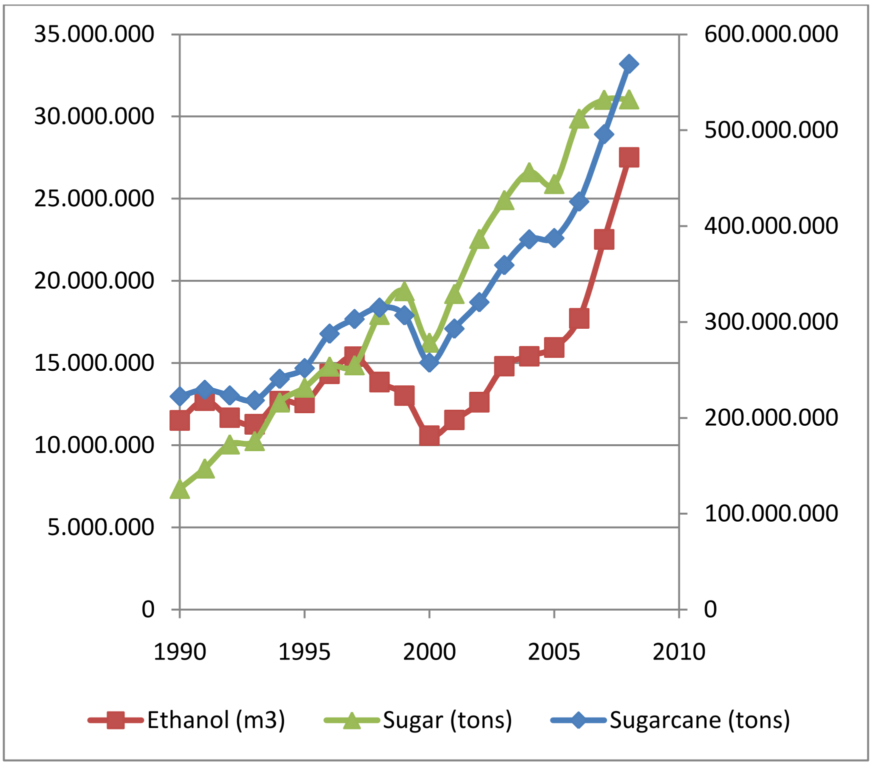

Figure 3 - Sugarcane, Ethanol and Sugar Production from 1990 to 2008

The reduction of incentives, combined with the high attractiveness of sugar led to a shortage of ethanol in the late '80s. The consumer confidence in ethanol technology declined dramatically and the result lack of confidence charged its price. Next paragraphs will discuss the effect of this decline in confidence in the will of consumer to buy a new ethanol car.

A car purchase is considered to be of high-involvement. Silbiger (2005) presents an interesting discussion on this concept:

> *"As the discussion or buyer behavior indicates, different products elicit different purchase behaviors because of their inherent importance to the buyer and user. If the consumer feels a high level of "risk" in buying a product, then it is considered a high-involvement product. There are several reasons for high-involvement purchase decisions: high price; the need for product's benefit; and the need for the product's psychological reward."*

Cars can be considered examples of high-involvement purchases since it commits a relevant amount of money, the customer needs product benefits and, sometimes, need the product psychological reward. Table 1 presents the Costumer Involvement Matrix, adapted from Henry Assael[7], apud Silbiger (2005).

---

[7] Assael, Henry. Consumer Behavior and Marketing Action, 4th ed. Boston: PWS-Kent Publishing Company, 1992.

Table 1- Consumer Involvement Matrix

	High Involvement	Low Involvement
Significant Differences	• Complex Process • Brand Loyalty	• Experiment • Random Behavior • Variety Seeking
Few Differences	• Ansiety Reduction • Baseless Belief about the Product	• Buy cheapest one • Random Behavior • Baseless Loyalty • Inertia

Silbiger (2005) continues:

> *A helpful matrix above captures the possible behaviors resulting from the interaction of the levels of involvement and product differences. By understanding the possible behaviors, it is possible to understand the reasons behind the consumer preferences.*

A fuel system is a significance difference in a high-involvement purchase (car). Since the confidence in ethanol declined due to the late the eights shortage, the consumer was no longer confident in this option. The consequence was that the sales of ethanol cars dropped dramatically. This can be seen in Figure 2, where after a local peak in 1988, the sales dropped, and after a small recovery, dropped away and never recovered.

Dynamic Hypothesis

Model Boundaries Diagram

Sterman (2000) affirms that: *"A model boundary chart summarizes the scope of the model by listing which key variables are included endogenously, which are exogenously, and which are excluded from the model"*. Table 2 shows the Model Boundaries for the model.

Table 2 - Model Boundaries

Included in the model		**Not included**
Endogenous	**Exogenous**	
Gasoline Fleet	Effect of Subsidies and Exemptions	Automakers Attractiveness for Ethanol Cars
Ethanol Fleet	Cars Demand	
Ethanol Learning Curve	International Sugar Price	
Production Schedule (Ethanol or Sugar)	Sugar Demand	
Sugarcane Industry Utilization (Simplified)		
Sugarcane Industry Capacity (Simplified)		
Sugarcane Demand Forecast		

Subsystem Diagram

Sterman (2000) affirms that: "*A subsystem diagram shows the overall architecture of a model*". Table 3 shows how subsystems affect each other. First column shows the origin; second column shows the word "affects"; third column shows the variable affected; fourth column shows the word "with"; and fifth column shows how the first variable affects the second. Letters representing subsystem as in subsystem diagram. Figure 4 shows the Subsystem Diagram for the model.

Table 3 - Relationships between agents

WHO	AFFECTS	WHO	WITH	HOW
GOV	Affects	SCI	with	Subsidies
GOV	Affects	CO	with	Taxes and Subsidies
SCI	Affects	CO	with	Ethanol Price
SCI	Affects	CO	with	Ethanol Production
CF	Affects	SCI	with	Ethanol Demand
CO	Affects	CF	with	Buying either Ethanol or Gasoline Cars
DEM	affects	CF	with	New cars

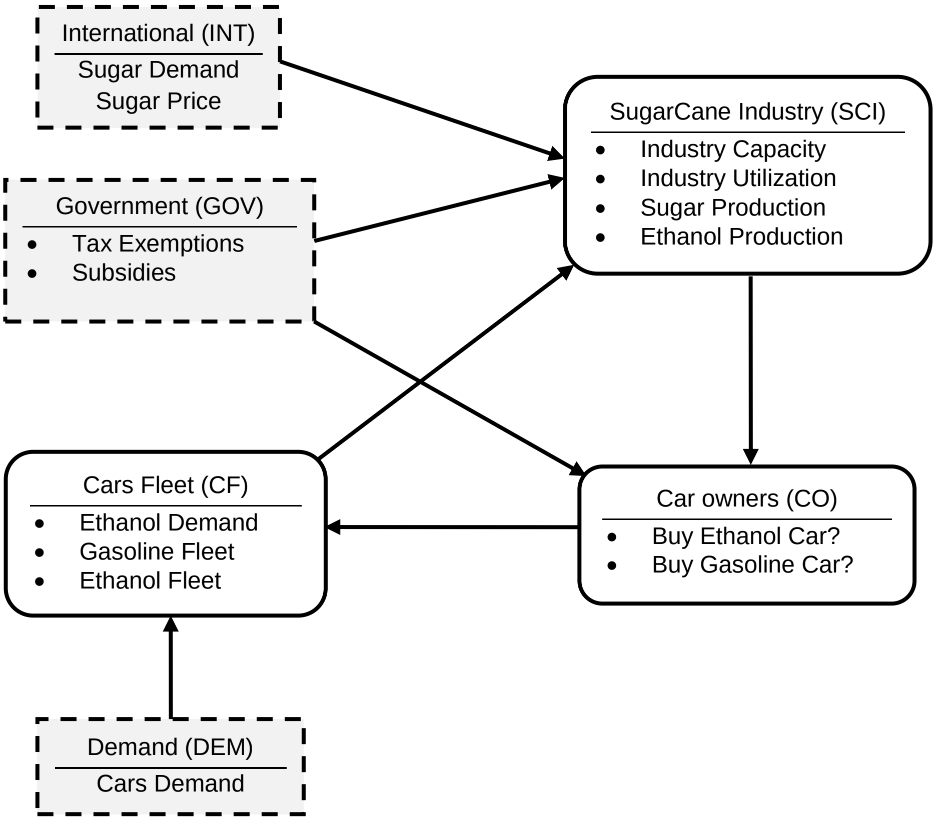

Figure 4 - Subsystem Diagram

Causal Loop Diagram

Figure 5 shows the Causal Loop Diagram for the system. It represents the dynamics of cars fleets; competition between sugar and ethanol for a common resource, the sugarcane industry capacity; the effect of government subsidies; and a simplified model of sugarcane industry behavior.

Gasoline Fleet increases with *New Gasoline Cars Rate*, which is a function of *Cars Demand*, *Gasoline Cars Attractiveness*, assumed constant in the model, and *Total Cars Attractiveness*. For simplicity, *Gasoline Cars Attractiveness* is assumed constant. This part of the diagrams shows the assumptions that attractiveness of gasoline cars have not changed during the period of ethanol cars and that demand was not affect by the system.

Ethanol Fleet increases with *New Ethanol Cars Rate*, which is a function of *Cars Demand*, *Ethanol Cars Attractiveness*, and *Total Cars Attractiveness*. Ethanol Cars Attractiveness is a function of four elements: *Effect of Exemptions from Taxes on Ethanol Cars*; *Effect of Ethanol Technology Maturity on Attractiveness*; *Effect of Ethanol Inventory Coverage on Ethanol Cars Attractiveness*; and *Other Aspects Affecting Ethanol Cars Attractiveness*.

Effect of Exemptions Taxes on Ethanol Cars Attractiveness is assumed exogenous, since it is a high Government decision level, not included in the model. *Other Aspects Affecting Ethanol Cars Attractiveness* models the E100 technology availability; therefore, it is assumed 0 before 1979 and it is assumed 1, from 1979 to the end of simulation.

When *Ethanol Fleets* increases it is a strong indication that the associated technology matures; maturation of ethanol technology leads to an increases in *Ethanol Cars Attractiveness*, which increases *New Ethanol Cars Sales*. This closes the positive loop *Maturity*.

Ethanol and *Gasoline Cars Fleet* increases *Ethanol Demand*, which is also influenced by *Gasohol Fraction Ratio*. Historically, Brazilian Government tries to attenuate business cycles in sugarcane industry by changing this variable. For simplicity, in this model *Gasohol Fraction Ratio* is assumed constant.

Ethanol Demand affects *Ethanol Price*, which is also affected by *Ethanol Inventory Coverage*, *Ethanol Costs*, and *Government Subsidies*.

Sugarcane Indicated Production is affected by *Sugar Demand* (exogenous) and *Ethanol Demand*. *Sugarcane Indicated Production* affects *Indicated Capacity*, after some delay, and *Sugarcane Production Rate*.

Sugarcane Production Rate is influenced by *Sugarcane Industrial Capacity* and *Sugarcane Indicated Production*. In this model the Industry Utilization was simplified, consistently whit model purposes. *Sugarcane Production Rate* increases *Sugarcane Inventory*, which decreases with *Sugarcane Processing Rate*.

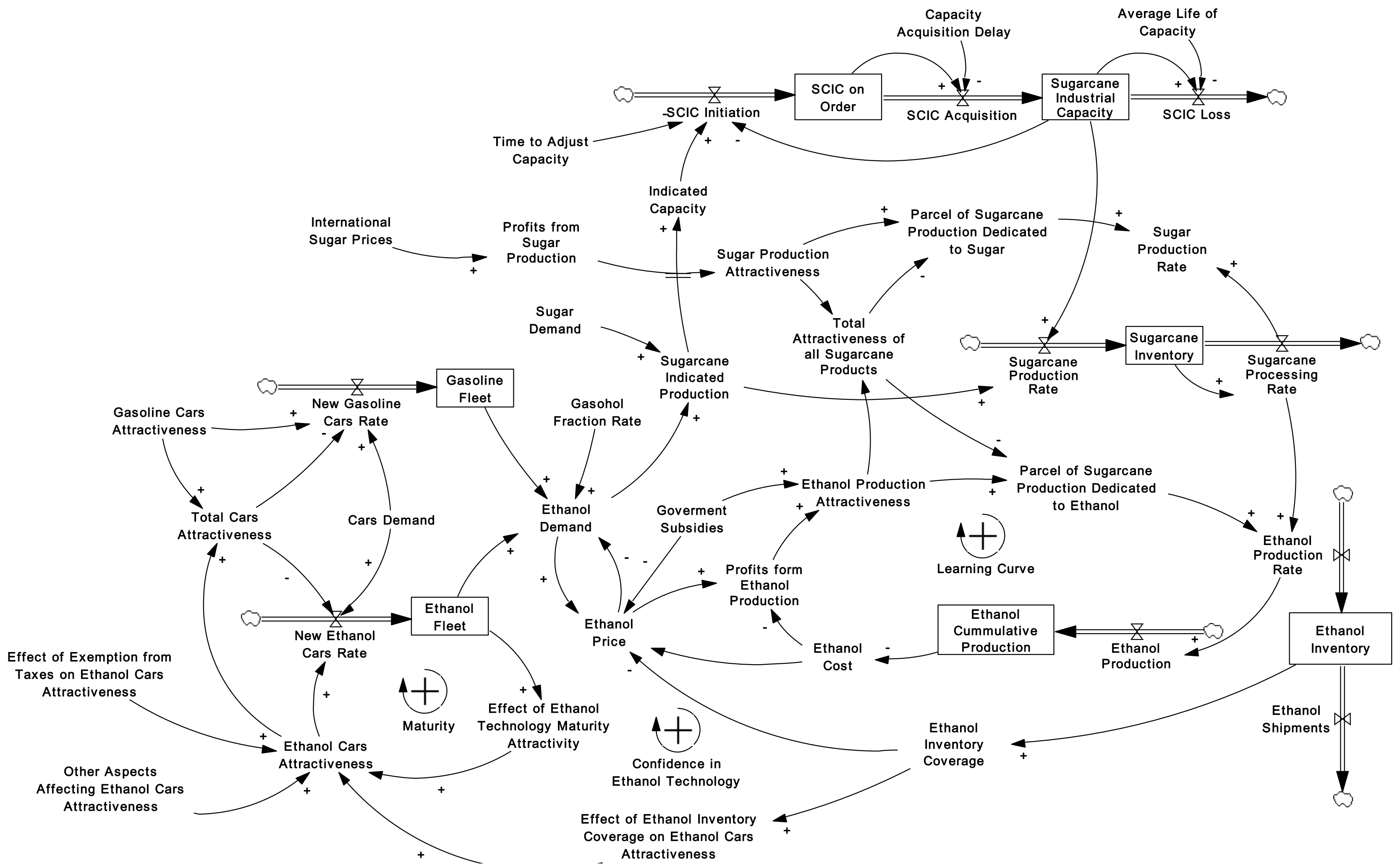

Figure 5 – Causal Loop Diagram

For simplicity, sugarcane production is supposed to produce only two products: sugar and ethanol. Part of Sugarcane Processing Rate is used for sugar production (*Sugar Production Rate*) and part for ethanol production (*Ethanol Production Rate)*. This decision is made taking into account the attractiveness of each product.

Parcel of Sugarcane Production Dedicated to Sugar is affected by *Sugar Production Attractiveness* and *Total Attractiveness of all Sugarcane Products*, which is a sum of *Sugar Production Attractiveness* and *Ethanol Production Attractiveness*. *Sugar Production Rate* is a function of *Parcel of Sugarcane Production Dedicated to Sugar and Sugarcane Processing Rate*.

Sugar Production Attractiveness is a function of *Profits from Sugar Production*, which is a function of *International Sugar Prices*. Two points deserve some attention: it is assumed that Brazilian sugar production does not affect international sugar prices, which is a simplification; and that since sugar production is a mature production and the effects of learning curve are constant. For our purposes both assumptions seem to be reasonable, and can be relaxed in future versions of the model.

As well as the *Sugar Production Attractiveness* is a function of *Profits from Sugar Production*, Ethanol Production Attractiveness is a function of *Profits from Ethanol Production*; however, this dependence is changed by *Government Subsidies*, so as to keep ethanol production attractive.

Loop *Learning Curve* starts with Profits from Ethanol Production. This profit affects *Ethanol Production Attractiveness*, which affects *Parcel of Sugarcane Production Dedicated to Ethanol*. Parcel dedicated to *Ethanol Production Rate* increases *Ethanol Cumulative Production*. The growth of cumulative production improves the production process and reduces the *Ethanol Costs*; this reduction in costs increases the profits. This closes the loop *Learning Curve*.

Ethanol Production Rate increases *Ethanol Inventory*, which is decreased by *Ethanol Shipments*. As *Ethanol Inventory* increases *Ethanol Inventory Coverage* increases with positive effect in customer’s confidence on technology success. As *Ethanol Inventory Coverage* increases *Effect of Ethanol Inventory Coverage on Ethanol Cars Attractiveness* increases and *Ethanol Cars Attractiveness* increases, as well. This description closes the relevant loop *Confidence in Ethanol Technology*. This loop will be responsible for the reduction in confidence of ethanol technology, leading to its decline.

The top right of the Causal Loop Diagram shows the structure of *Sugarcane Industrial Capacity* (*SCIC*). *Indicated Capacity* is calculated from *Sugarcane Indicated Production* through a TREND[8] function. Acquisition initiation of SCIC (*SCIC Initiation*) is calculated comparing *Indicated Capacity* with *Sugarcane Industrial Capacity*, over *Time to Adjust Capacity*.

Sugarcane industrial capacity on order (*SCIC on Order*) accumulates the difference between *SCIC Initiation* and *SCIC Acquisition*. When the new capacity is ready for operational purposes, it is delivered to the industry (*SCIC Acquisition*), decreasing *SCIC on Order*. The construction of new capacity takes time (*Capacity Acquisition Delay*), and this delay have proved to be a source of oscillations. In this model, potential problems with Capacity Supply Chain structure was not explored, but it may be done in future developments.

---

[8] See Sterman (2000, Chapter 16) for a complete explanation of TREND function.

Sugarcane industrial capacity accumulates the difference between *SCIC Acquisition* and *SCIC Loss*. SCIC captures the dynamic of obsolescence of capacity. It is modeled as a first order delay, with time constant equal to *Average Life of Capacity*.

Simulation Model

Sterman (2000, p. 37) affirms:

> *"Eliciting and mapping the participants' mental models, while necessary, is far from sufficient. As discussed above, the temporal and spatial boundaries of our mental models tend to be too narrow. They are dynamically deficient, omitting feedbacks, time delays, accumulations, and nonlinearities"*

Sterman states that the way to overcome these issues is to simulate. He points out that simulation is the only practical way to test our mental models, since their complexity vastly exceeds our capacity to understand their implications.

In this paper, the simulation model has two different purposes: the first is to verify the consistence or our mental model; and the second is to allow some policy tests. Model general structure and simulation techniques are based on Sterman (2000).

Model was developed using Vensim Standard, version 5.5d. Equations presented in this paper follows the software format.

Simulation model was developed with 11 views, each one representing a sector of the model. Views names are: Fleet Sector; Production and Inventory; Sugarcane Capacity Utilization; Sugarcane Production Capacity; Desired Capital; Demand; Sugarcane Demand Forecast; Production Schedule; Effect of Scarcity; Auxiliary; and Reference Mode. Each view is explained in detail in next sections of this paper.

Fleet Sector

The structure of Fleet Sector is based on Sterman's proposal for a simple model of network effects, with minor changes. Figure 6 shows the structure of the Fleet Sector. The diagram represents two competing products (Ethanol Cars and Gasoline Cars) competing to be the standard in the market.

The fleet of each type is increase by the sales of each model (ethanol or gasoline) and decrease by discards.

*Gasoline Cars Fleet= INTEG (Sales of New Gasoline Cars-Scrap of Old Gasoline Cars,
Initial Gasoline Fleet); Units: Cars*

*Ethanol Cars Fleet= INTEG (Sales of New Ethanol Cars-Scrap of Old Ethanol Cars,
Initial Ethanol Fleet); Units: Cars*

The sales of each car type is the product of total demand and its market share:

*Sales of New Gasoline Cars=Total Demand * Market Share of Gasoline Cars; Units: Cars/Year*

*Sales of New Gasoline Cars=Total Demand * Market Share of Gasoline Cars; Units: Cars/Year*

The discards of each cart type is defined as a first order delay.

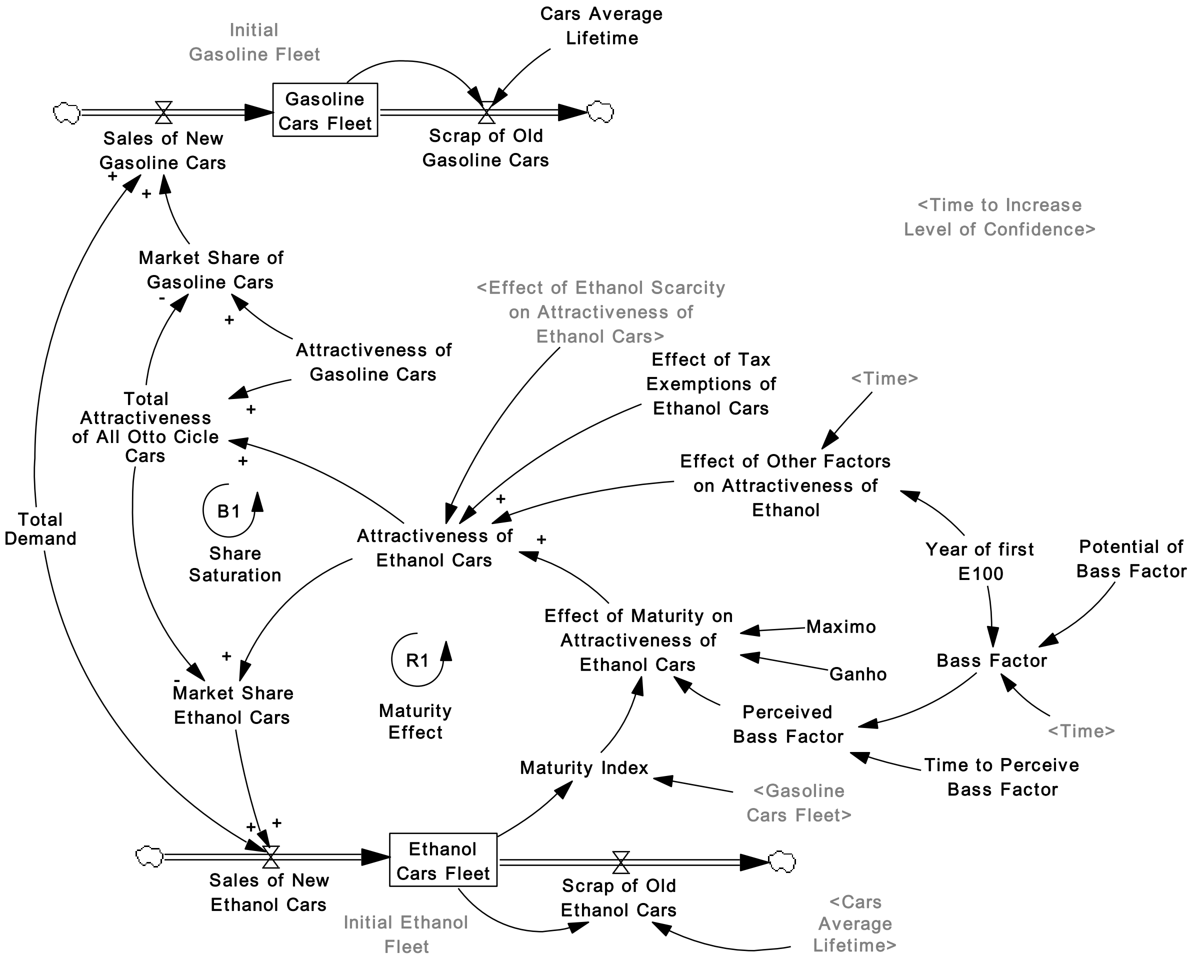

Figure 6- Forrester Diagram - Fleet Sector

Scrap of Old Gasoline Cars=Gasoline Cars Fleet/Cars Average Lifetime; Units: Cars/Year

Scrap of Old Ethanol Cars=Ethanol Cars Fleet/Cars Average Lifetime; Units: Cars/Year

Cars Average Lifetime= 25; Units: Year

For simplicity, it is assumed that demand is exogenous and constant.

Market share is determined by the attractiveness of each of each technology, relative to the attractiveness of others.

Market Share of Gasoline Cars=Attractiveness of Gasoline Cars/Total Attractiveness of All Otto Cicle Cars; Units: Dimensionless

Market Share Ethanol Cars=Attractiveness of Ethanol Cars/Total Attractiveness of All Otto Cicle Cars; Units: Dimensionless

Total Attractiveness of All Otto Cicle Cars=Attractiveness of Gasoline Cars + Attractiveness of Ethanol Cars; Units: Dimensionless

For simplicity, the Gasoline technology is assumed fully mature and its attractiveness is assumed constant and equal 1.

Attractiveness of Gasoline Cars=1; Units: Dimensionless

Attractiveness of ethanol cars is a function of technology maturity, exemption of taxes, and other factors.

*Attractiveness of Ethanol Cars= Effect of Maturity on Attractiveness of Ethanol Cars*Effect of Other Factors on Attractiveness of Ethanol*Effect of Tax Exemptions of Ethanol Cars; Units: Dimensionless*

Effect of other factors is assumed to be a step function. Before ethanol technology is launched, It is assumed zero, after it is assumed one.

Effect of Other Factors on Attractiveness of Ethanol=IF THEN ELSE(Time < 5, 0 , 1); Units: Dimensionless

Ethanol cars received subsidies from Brazilian Government. One subsidy was a reduction of taxes when a new ethanol car is bought. Since the ethanol cars sales achieved nine times the gasoline cars sales, the effect of this exemption is assumed to be equal to nine

Effect of Tax Exemptions of Ethanol Cars=30; Units: Dimensionless

Effect of technology maturity is assumed to be a non-linear function of technology maturity. This function is bounded in its minimum and maximum value. Minimum value represents the parcel of Bass model and captures the effect of initial advertising. Maximum Value captures the upper limit of maturity effect; when the ethanol technology is fully mature, the effect of its maturity is assumed equal as the gasoline technology. Variable *Ganho* captures the dynamics the slope of the effect of maturity.

*Effect of Maturity on Attractiveness of Ethanol Cars=MAX(Perceived Bass Factor, MIN(Maximo, Ganho*Maturity Index)); Units: Dimensionless*

Maximo=1; Units: Dimensionless

Ganho=12; Units: Dimensionless

Perceived Bass Factor captures the dynamics of the delay of the population awareness of advertising; it is assumed to be a first order delay of the *Bass Factor*.

Perceived Bass Factor=DELAY1I(Bass Factor, Time to Perceive Bass Factor, 0); Units: Dimensionless

Bass Factor=IF THEN ELSE(Time>=Year of first E100, Potential of Bass Factor , 0); Units: Dimensionless

Time to Perceive Bass Factor=1; Units: Year

Maturity Index represents the percentage of ethanol cars on total fleet. As this number increases, it is reasonable to assume that the technology matures.

Maturity Index=Ethanol Cars Fleet/(Gasoline Cars Fleet + Ethanol Cars Fleet); Units: Dmnl

Sugarcane Production and Inventory Sector

This sector represents the dynamics of the Sugarcane Production and Inventory Sector. Final version of this paper will contain an explanation as detailed as the one presented in Fleet Sector. For now only the Forrester Diagram and equations are presented.

Ethanol Cummutative Production= INTEG (Ethanol Production Rate,0);   Units: Units of Ethanol

Ethanol Desired Shipment Rate=Ethanol Demand from Ethanol Cars+Ethanol Demand from Gasoline Cars; Units: Units of Ethanol/Year

*Ethanol Inventory= INTEG (Ethanol Production Rate-Ethanol Shipment Rate, Ethanol Desired Shipment Rate*Ethanol Desired Inventory Coverage); Units: Units of Ethanol*

Ethanol Inventory Coverage=ZIDZ(Ethanol Inventory, Ethanol Shipment Rate); Units: Year

Ethanol Order Fulfillment Ratio=Ethanol Shipment Rate/Ethanol Desired Shipment Rate; Units: Dimensionless

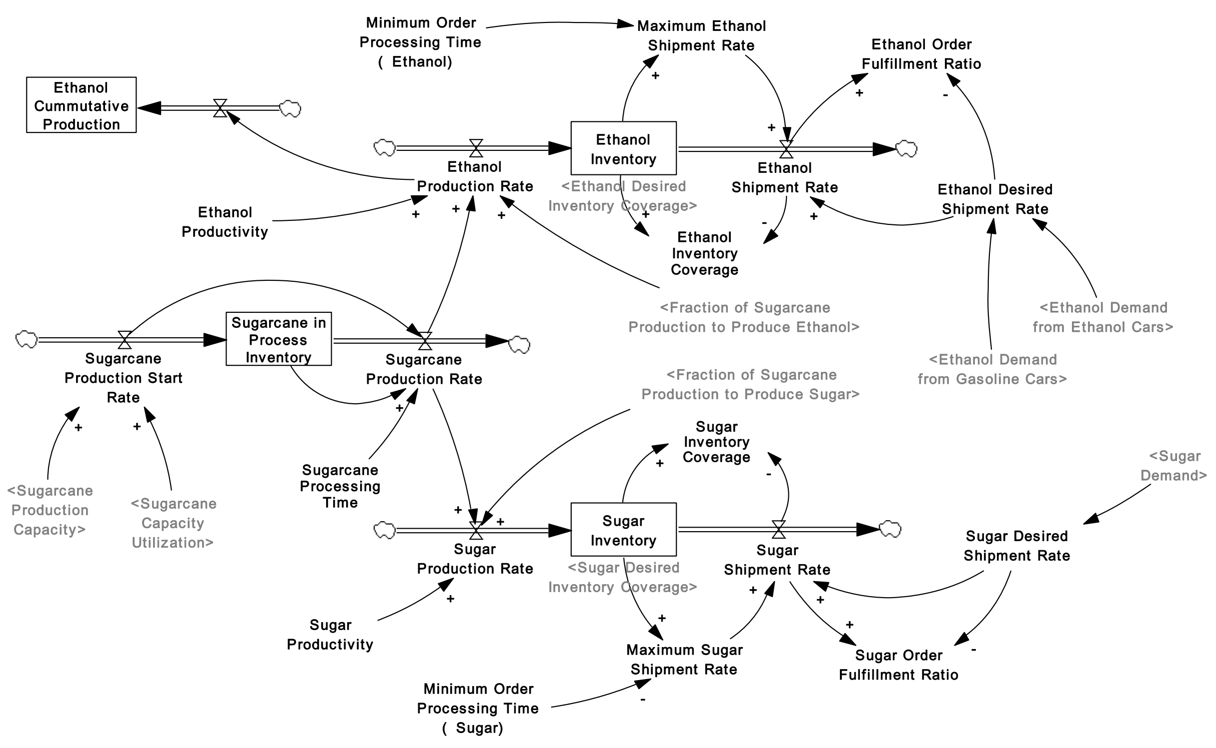

Figure 7 - Forrester Diagram - Production and Inventory Sector

*Ethanol Production Rate=Sugarcane Production Rate*Fraction of Sugarcane Production to Produce Ethanol*Ethanol Productivity; Units: Units of Ethanol/Year*

Ethanol Productivity=0.068; Units: Units of Ethanol / Units of Sugarcane

Ethanol Shipment Rate=MIN(Ethanol Desired Shipment Rate,Maximum Ethanol Shipment Rate); Units: Units of Ethanol/Year

Maximum Ethanol Shipment Rate=Ethanol Inventory/"Minimum Order Processing Time (Ethanol)"; Units: Units of Ethanol/Year

Maximum Sugar Shipment Rate=Sugar Inventory/"Minimum Order Processing Time (Sugar)"; Units: Units of Sugar/Year

"Minimum Order Processing Time (Ethanol)"=0.25; Units: Year

"Minimum Order Processing Time (Sugar)"=0.25; Units: Year

Sugar Desired Shipment Rate=Sugar Demand; Units: Units of Sugar/Year

*Sugar Inventory= INTEG (Sugar Production Rate-Sugar Shipment Rate,Sugar Desired Shipment Rate*Sugar Desired Inventory Coverage); Units: Units of Sugar*

Sugar Inventory Coverage=ZIDZ(Sugar Inventory, Sugar Shipment Rate); Units: Year

Sugar Order Fulfillment Ratio=Sugar Shipment Rate/Sugar Desired Shipment Rate; Units: Dimensionless

*Sugar Production Rate=Sugarcane Production Rate*Fraction of Sugarcane Production to Produce Sugar*Sugar Productivity; Units: Units of Sugar/Year*

Sugar Productivity=0.2; Units: Units of Sugar/Units of Sugarcane

Sugar Shipment Rate=MIN(Maximum Sugar Shipment Rate,Sugar Desired Shipment Rate); Units: Units of Sugar/Year

*Sugarcane in Process Inventory= INTEG (Sugarcane Production Start Rate-Sugarcane Production Rate, (Ethanol Desired Shipment Rate/Ethanol Productivity+Sugar Desired Shipment Rate/Sugar Productivity)*Sugarcane Processing Time); Units: Units of Sugarcane*

Sugarcane Processing Time=0.5; Units: Year

Sugarcane Production Rate=MIN(Sugarcane in Process Inventory/Sugarcane Processing Time, DELAY3I(Sugarcane Production Start Rate, Sugarcane Processing Time,Sugarcane Production Start Rate)); Units: Units of Sugarcane/Year

*Sugarcane Production Start Rate=Sugarcane Production Capacity*Sugarcane Capacity Utilization; Units: Units of Sugarcane/Year*

Sugarcane Capacity Utilization Sector

This sector represents the dynamics of the Sugarcane Capacity Utilization Sector. Final version of this paper will contain an explanation as detailed as the one presented in Fleet Sector. For now only the Forrester Diagram and equations are presented.

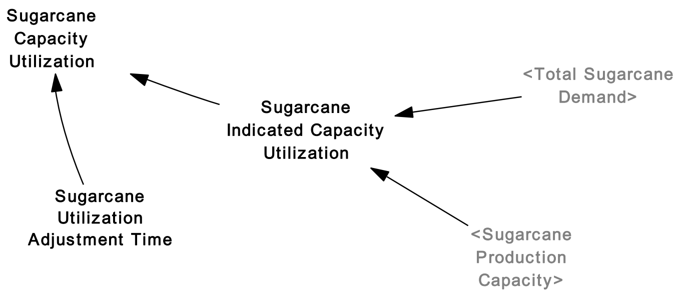

Figure 8 - Forrester Diagram - Sugarcane Capacity Utilization Sector

Sugarcane Capacity Utilization=SMOOTH(Sugarcane Indicated Capacity Utilization , Sugarcane Utilization Adjustment Time); Units: Dimensionless

Sugarcane Indicated Capacity Utilization=MIN(1,Total Sugarcane Demand/Sugarcane Production Capacity); Units: Dimensionless

Sugarcane Utilization Adjustment Time=0.5; Units: Year

Sugarcane Production Capacity Sector

This sector represents the dynamics of the Sugarcane Production Capacity Sector. Final version of this paper will contain an explanation as detailed as the one presented in Fleet Sector. For now only the Forrester Diagram and equations are presented.

Acquisition Rate=MIN(Capital on Order/Capacity Acquisition Delay, DELAY3I(Order Rate, Capacity Acquisition Delay , Order Rate)); Units: Unit of Capital/Year

Adjustment for Capacity=(Desired Capital-Capital Stock)/Capacity Adjustment Time; Units: Unit of Capital/Year

Adjustment for Supply Line=(Desired Supply Line-Capital on Order)/Supply Line Adjustmen Time; Units: Unit of Capital/Year

Average Life of Capacity=20; Units: Year

Capacity Acquisition Delay=2; Units: Year

Capacity Adjustment Time=3; Units: Year

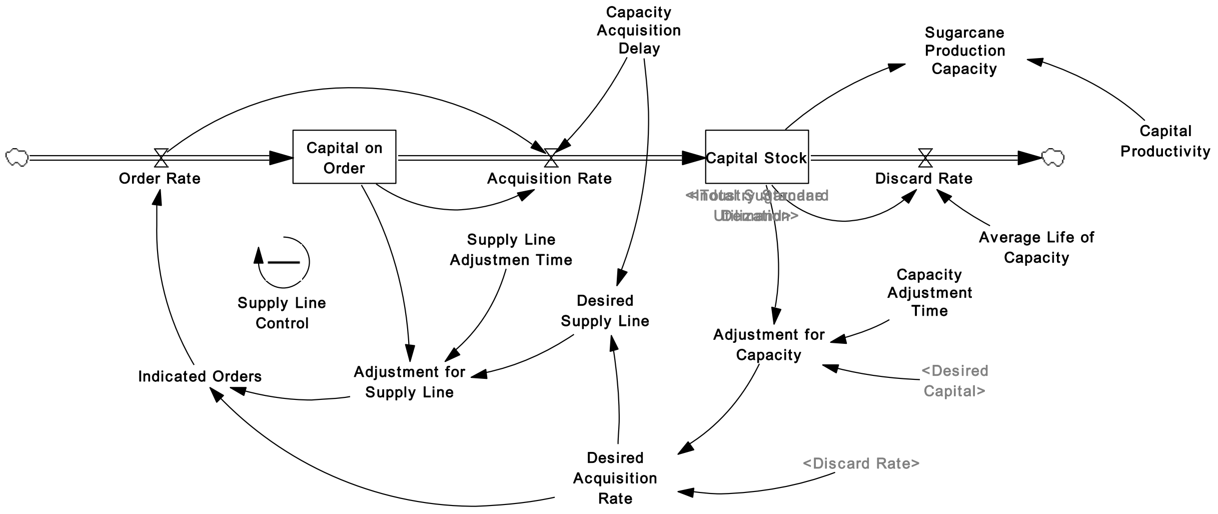

Figure 9 - Forrester Diagram - Sugarcane Production Capacity Sector

*Capital on Order= INTEG (Order Rate-Acquisition Rate,Discard Rate*Capacity Acquisition Delay); Units: Unit of Capital*

Capital Productivity=1; Units: Units of Sugarcane/Unit of Capital/Year

Capital Stock= INTEG (Acquisition Rate-Discard Rate, Total Sugarcane Demand/Industry Standard Utilization/Capital Productivity); Units: Unit of Capital

Desired Acquisition Rate=Adjustment for Capacity+Discard Rate; Units: Unit of Capital/Year

*Desired Supply Line=Capacity Acquisition Delay*Desired Acquisition Rate; Units: Unit of Capital*

Discard Rate=Capital Stock/Average Life of Capacity; Units: Unit of Capital/Year

Indicated Orders=Desired Acquisition Rate+Adjustment for Supply Line; Units: Unit of Capital/Year

Order Rate=MAX(0, Indicated Orders); Units: Unit of Capital/Year

*Sugarcane Production Capacity=Capital Stock*Capital Productivity; Units: Units of Sugarcane/Year*

Supply Line Adjustmen Time=1; Units: Year

Desired Capital Sector

This sector represents the dynamics of the Desired Capital Sector. Final version of this paper will contain an explanation as detailed as the one presented in Fleet Sector. For now only the Forrester Diagram and equations are presented.

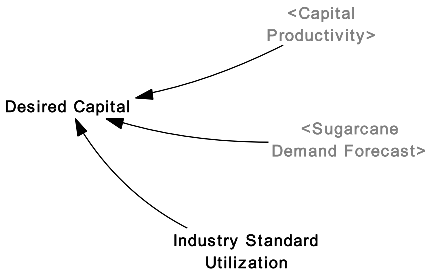

Figure 10 - Forrester Diagram - Desired Capital Sector

Desired Capital=Sugarcane Demand Forecast/Capital Productivity/Industry Standard Utilization; Units: Unit of Capital

Industry Standard Utilization=0.8; Units: Dimensionless

Demand Sector

This sector represents the dynamics of the Demand Sector. Final version of this paper will contain an explanation as detailed as the one presented in Fleet Sector. For now only the Forrester Diagram and equations are presented.

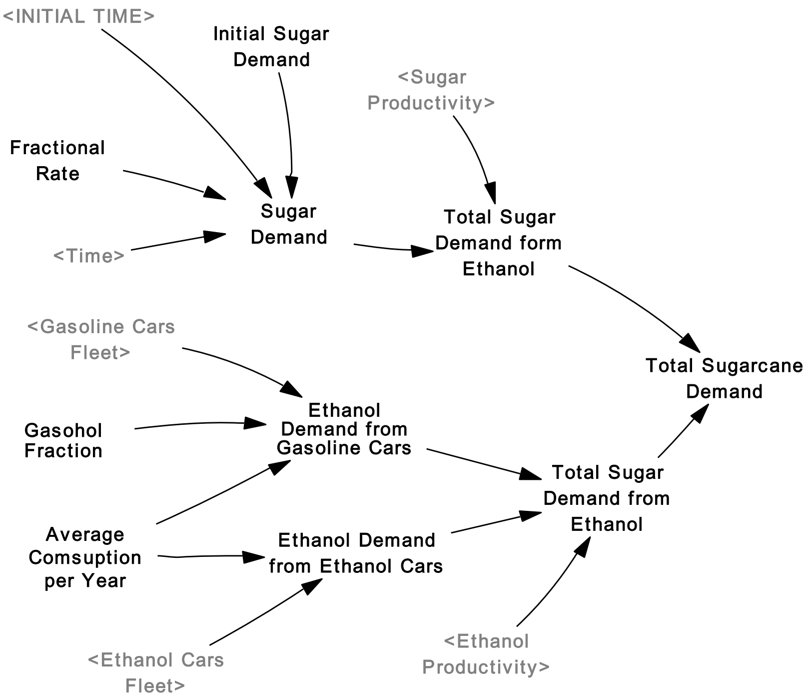

Figure 11 - Forrester Diagram - Demand Sector

*Average Comsuption per Year= 2.2; Units: Units of Ethanol/(Cars*Year)*

*Ethanol Demand from Ethanol Cars=Ethanol Cars Fleet*Average Comsuption per Year; Units: Units of Ethanol/Year*

*Ethanol Demand from Gasoline Cars=Gasoline Cars Fleet*Gasohol Fraction*Average Comsuption per Year; Units: Units of Ethanol/Year*

Fractional Rate=0.13; Units: Dimensionless/Year

Gasohol Fraction=0.22; Units: Dmnl

Initial Sugar Demand=825000; Units: Units of Sugar/Year

*Sugar Demand=Initial Sugar Demand*exp(Fractional Rate*(Time-INITIAL TIME)); Units: Units of Sugar/Year*

Total Sugar Demand from Ethanol=Sugar Demand/Sugar Productivity; Units: Units of Sugarcane/Year

Total Sugar Demand from Ethanol=(Ethanol Demand from Gasoline Cars+Ethanol Demand from Ethanol Cars)/Ethanol Productivity; Units: Units of Sugarcane/Year

Total Sugarcane Demand=Total Sugar Demand form Ethanol+Total Sugar Demand from Ethanol; Units: Units of Sugarcane/Year

Sugarcane Demand Forecast Sector

This sector represents the dynamics of the Sugarcane Demand Forecast Sector. Final version of this paper will contain an explanation as detailed as the one presented in Fleet Sector. For now only the Forrester Diagram and equations are presented.

Change in Perceived Present Condition=(Total Sugarcane Demand-Perceived Present Condition)/Time to Perceive Present Condition; Units: Units of Sugarcane/Year/Year

Change in Reference Condition=(Perceived Present Condition-Reference Condition)/Time Horizon for Reference Condition; Units: Units of Sugarcane/Year/Year

Change in Trend=(Indicated Trend-Perceived Trend)/Time to Perceive Trend; Units: 1/Year/Year

Indicated Trend=ZIDZ(Perceived Present Condition-Reference Condition, Reference Condition)/Time Horizon for Reference Condition; Units: 1/Year

Perceived Present Condition= INTEG (Change in Perceived Present Condition,Total Sugarcane Demand); Units: Units of Sugarcane/Year

Perceived Trend= INTEG (Change in Trend,"Perceived Trend (1975)"); Units: 1/Year

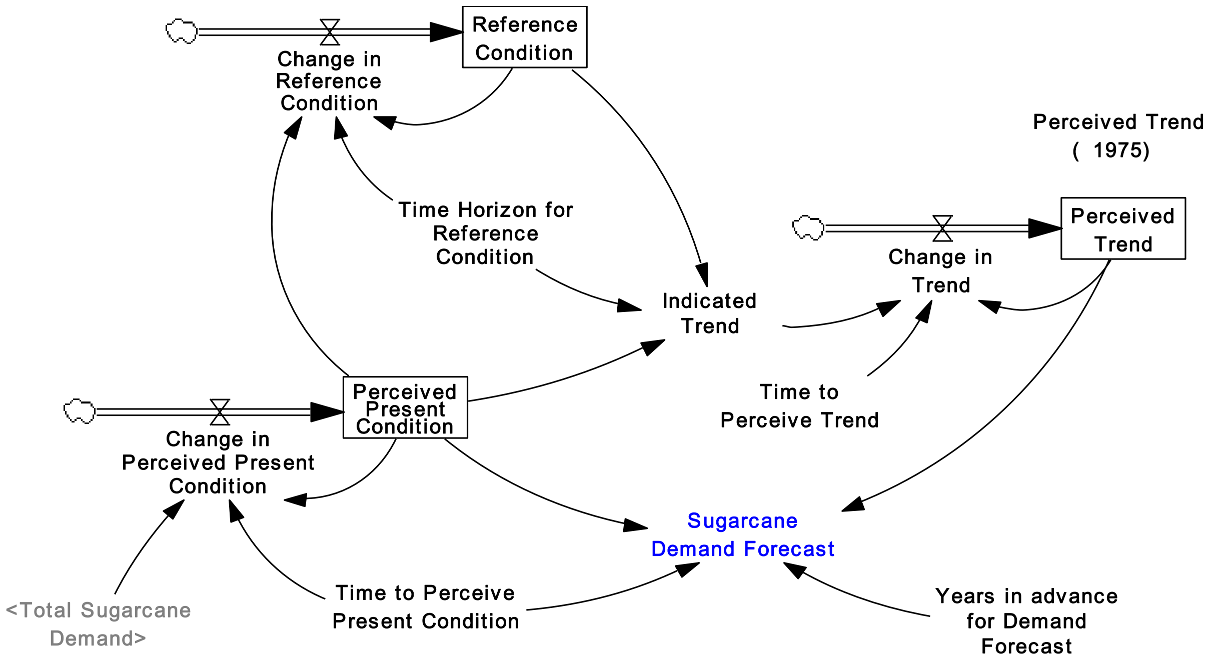

Figure 12 - Forrester Diagram - Sugarcane Demand Forecast

"Perceived Trend (1975)"=0; Units: 1/Year

Reference Condition= INTEG (Change in Reference Condition,Total Sugarcane Demand); Units: Units of Sugarcane/Year

Sugarcane Demand Forecast=Perceived Present Condition(1+Perceived Trend*Time to Perceive Present Condition)*exp(Perceived Trend*Years in advance for Demand Forecast); Units: Units of Sugarcane/Year*

Time Horizon for Reference Condition=2; Units: Year

Time to Perceive Present Condition=0.5; Units: Year

Time to Perceive Trend=0.5; Units: Year

Years in advance for Demand Forecast=1; Units: Year

Production Schedule Sector

This sector represents the dynamics of the Production Schedule Sector. Final version of this paper will contain an explanation as detailed as the one presented in Fleet Sector. For now only the Forrester Diagram and equations are presented.

Attractiveness of All Sugarcane Products=Attractiveness of Ethanol Production+Attractiveness of Sugar Production; Units: Dimensionless

*Attractiveness of Ethanol Production=Effect of Inventory Coverage on Ethanol Production Attractiveness*Perceived Effect of Profits on Attractiveness of Ethanol Production; Units: Dimensionless*

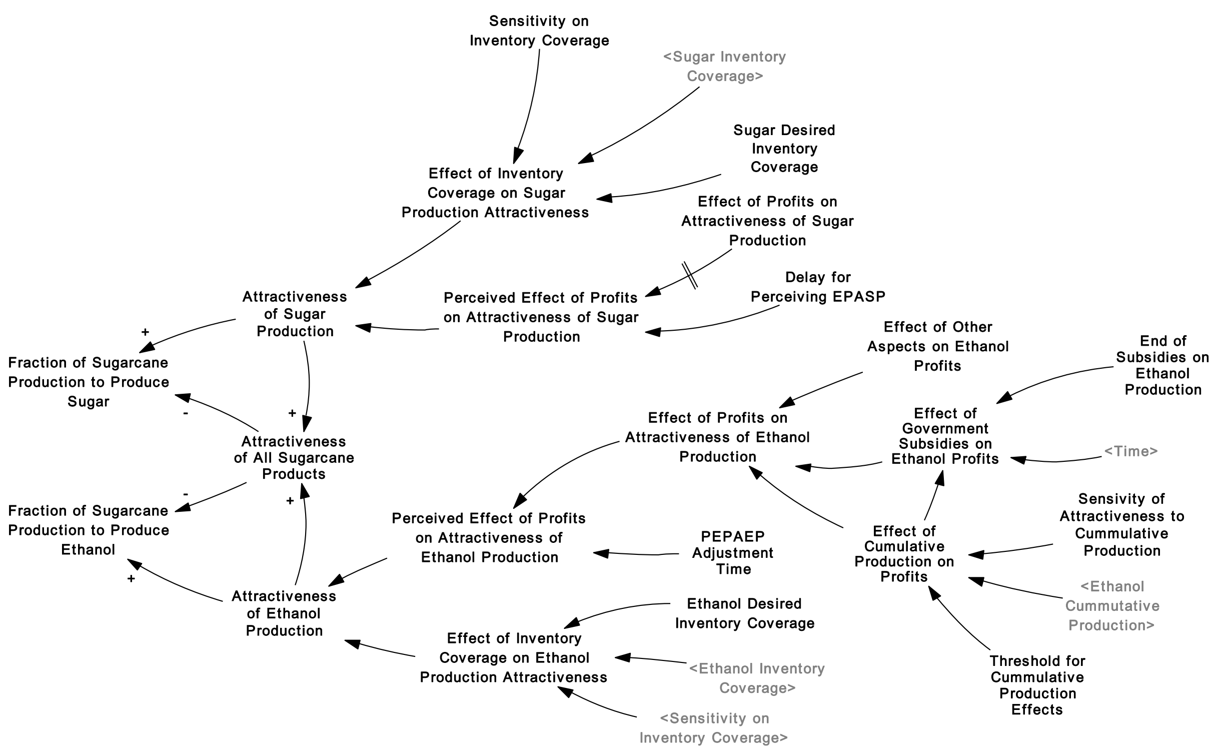

Figure 13 - Forrester Diagram - Production Schedule Sector

*Attractiveness of Sugar Production=Effect of Inventory Coverage on Sugar Production Attractiveness*Perceived Effect of Profits on Attractiveness of Sugar Production; Units: Dimensionless*

Delay for Perceiving EPASP=1; Units: Year

*Effect of Cumulative Production on Profits=1.5-exp(Sensivity of Attractiveness to Cummulative Production*Ethanol Cummutative Production/Threshold for Cummulative Production Effects); Units: Dimensionless*

Effect of Government Subsidies on Ethanol Profits=IF THEN ELSE(Time>=End of Subsidies on Ethanol Production, 0.5, 1/Effect of Cumulative Production on Profits); Units: Dimensionless

Effect of Inventory Coverage on Ethanol Production Attractiveness=(Ethanol Desired Inventory Coverage/Ethanol Inventory Coverage)^Sensitivity on Inventory Coverage; Units: Dimensionless

Effect of Inventory Coverage on Sugar Production Attractiveness=(Sugar Desired Inventory Coverage/Sugar Inventory Coverage)^Sensitivity on Inventory Coverage; Units: Dimensionless

Effect of Other Aspects on Ethanol Profits=1; Units: Dimensionless

*Effect of Profits on Attractiveness of Ethanol Production=Effect of Other Aspects on Ethanol Profits*Effect of Government Subsidies on Ethanol Profits*Effect of Cumulative Production on Profits; Units: Dimensionless*

Effect of Profits on Attractiveness of Sugar Production:=GET XLS DATA('Reference Mode.xlsx', 'SugarAttractiveness' , 'A' , 'C2'); Units: Dimensionless

End of Subsidies on Ethanol Production=1985; Units: Year

Ethanol Desired Inventory Coverage=1; Units: Year

Fraction of Sugarcane Production to Produce Ethanol=Attractiveness of Ethanol Production/Attractiveness of All Sugarcane Products; Units: Dimensionless

Fraction of Sugarcane Production to Produce Sugar=Attractiveness of Sugar Production/Attractiveness of All Sugarcane Products; Units: Dimensionless

PEPAEP Adjustment Time=1; Units: Year

Perceived Effect of Profits on Attractiveness of Ethanol Production=DELAY1I(Effect of Profits on Attractiveness of Ethanol Production, PEPAEP Adjustment Time, Effect of Profits on Attractiveness of Ethanol Production); Units: Dimensionless

Perceived Effect of Profits on Attractiveness of Sugar Production=DELAY1I(Effect of Profits on Attractiveness of Sugar Production, Delay for Perceiving EPASP, Effect of Profits on Attractiveness of Sugar Production); Units: Dimensionless

Sensitivity on Inventory Coverage=0.5; Units: Dimensionless

Sensivity of Attractiveness to Cummulative Production=-1; Units: Dimensionless

Sugar Desired Inventory Coverage=1; Units: Year

Threshold for Cumulative Production Effects= 3e+007; Units: Units of Ethanol

Effect of Scarcity Sector

This sector represents the dynamics of the Effect of Scarcity Sector. Final version of this paper will contain an explanation as detailed as the one presented in Fleet Sector. For now only the Forrester Diagram and equations are presented.

Adjusted Ethanol Order Fulfillment Ratio=IF THEN ELSE(Time<=Year of first E100, Ethanol Order Fulfillment Ratio, MIN(1,Ethanol Order Fulfillment Ratio/Effect of Maturity on Attractiveness of Ethanol Cars)); Units: Dimensionless

Effect of Ethanol Scarcity on Attractiveness of Ethanol Cars=(Level of Confidence/"Level of Confidence (0)")^Sensititivy of Attrativeness of Ethanol Cars to Ethanol Scarcity; Units: Dimensionless

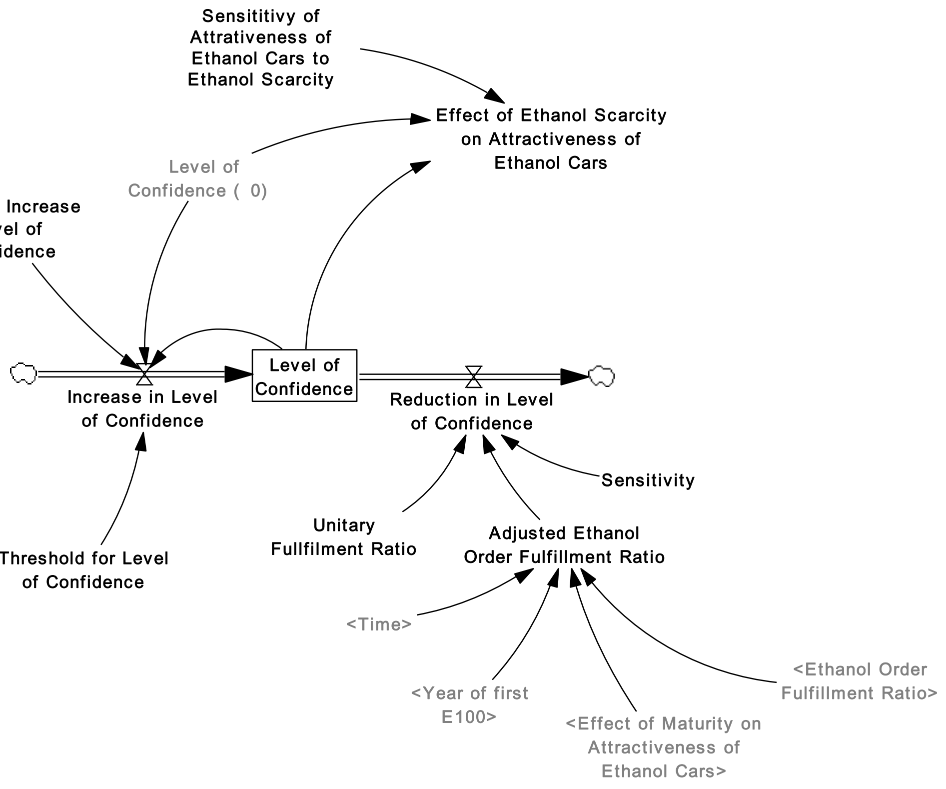

Figure 14 - Forrester Diagram - Scarcity Sector

Increase in Level of Confidence=IF THEN ELSE(Level of Confidence<Threshold for Level of Confidence, 0 , ("Level of Confidence (0)"-Level of Confidence)/Time to Increase Level of Confidence); Units: Dimensionless

*Level of Confidence= INTEG (Increase in Level of Confidence-Reduction in Level of Confidence, "Level of Confidence (0)"); Units: Dimensionless*Year*

*"Level of Confidence (0)"=1; Units: Dimensionless*Year*

Reduction in Level of Confidence=(Unitary Fullfilment Ratio-Adjusted Ethanol Order Fulfillment Ratio)^Sensitivity; Units: Dimensionless

Sensititivy of Attrativeness of Ethanol Cars to Ethanol Scarcity=6; Units: Dimensionless

Sensitivity=1; Units: Dimensionless

*Threshold for Level of Confidence=0.35; Units: Dimensionless*Year*

Time to Increase Level of Confidence=11; Units: Year

Unitary Fullfilment Ratio=1; Units: Dimensionless

Auxiliary Sector

This sector represents the dynamics of the Auxiliary Sector. Final version of this paper will contain an explanation as detailed as the one presented in Fleet Sector. For now only the Forrester Diagram and equations are presented.

Figure 15 - Forrester Diagram - Auxiliary Sector

"Sales of New Ethanol Cars (%)"=Sales of New Ethanol Cars/Total Sales; Units: Dimensionless

"Sales of New Gasoline Cars (%)"=Sales of New Gasoline Cars/Total Sales; Units: Dimensionless

Total Fleet=Ethanol Cars Fleet+Gasoline Cars Fleet; Units: Cars

Total Sales=Sales of New Ethanol Cars+Sales of New Gasoline Cars; Units: Cars/Year

Reference Mode Sector

This sector represents the variable in the Reference Mode Sector. Final version of this paper will contain an explanation as detailed as the one presented in Fleet Sector. For now only the Forrester Diagram and equations are presented.

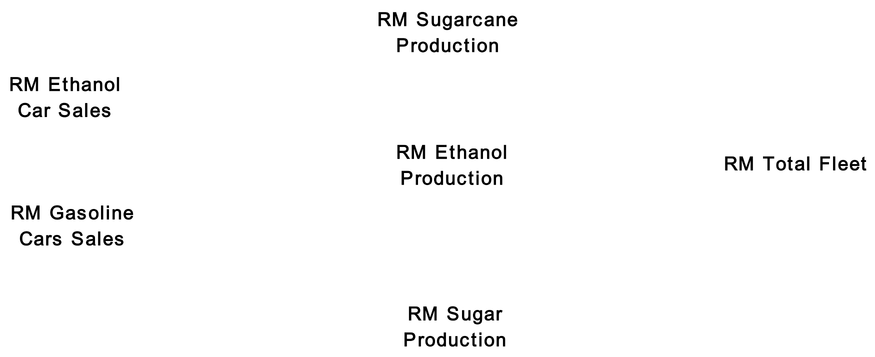

Figure 16 - Forrester Diagram - Reference Mode Sector

RM Ethanol Production:=GET XLS DATA('Reference Mode.xlsx', 'SugarCaneIndustryProduction' , 'A' , 'C2'); Units: Units of Ethanol/Year

RM Sales of New Ethanol Cars:=GET XLS DATA('Reference Mode.xlsx', 'VendasVeiculos' , 'A' , 'C2'); Units: Cars/Year

RM Sales of New Gasoline Cars:=GET XLS DATA('Reference Mode.xlsx', 'VendasVeiculos' , 'A' , 'B2'); Units: Cars

RM Sugar Production:=GET XLS DATA('Reference Mode.xlsx', 'SugarCaneIndustryProduction' , 'A' , 'D2'); Units: Units of Sugar/Year

RM Sugarcane Production:=GET XLS DATA('Reference Mode.xlsx', 'SugarCaneIndustryProduction', 'A' , 'B2'); Units: Units of Sugarcane/Year

RM Total Fleet:=GET XLS DATA('Reference Mode.xlsx', 'FrotaVeiculos' , 'A' , 'B2'); Units: Cars

Results

This section has two different parts. The first compares the behavior of the model with real data; and the second explores the model so as to understand the consequences of a sudden change in ethanol demand. This change is supposed to be similar to an abrupt change in government policies concerning biofuels.

Comparing the results with actual data available

The model presented in this paper is a preliminary version to explore the dynamics of the Ethanol Industry in Brazil and was not calibrated. Although, a comparison with some real, reference modes, were conducted so as to assure an adequate level of confidence. Therefore, the aim here is not to get a good fit, but to guarantee that the model behavior like the real system, qualitatively.

To test the model behavior six variables were compared with available data: *Sales of New Ethanol Cars* (Figure 17); *Sales of New Gasoline Cars* (Figure 18); *Sugarcane Production* (Figure 19); *Ethanol Production* (Figure 20); *Sugar Production* (Figure 21); and *Cars Fleet* (Figure 22).

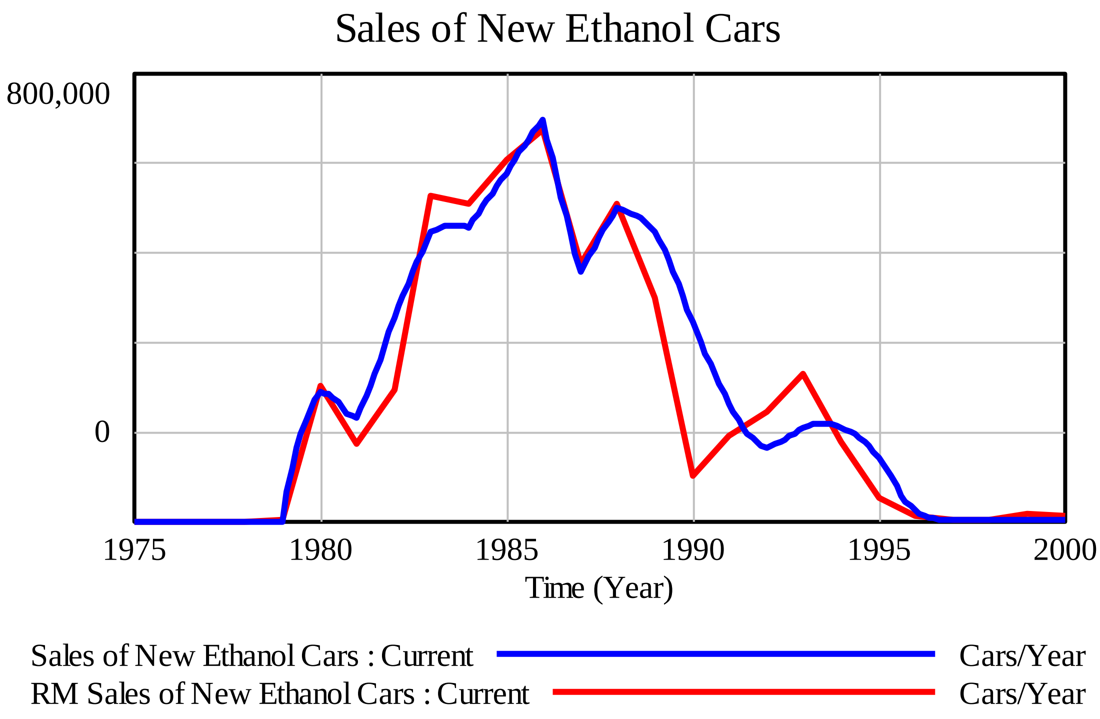

Figure 17 - Sales of New Ethanol Cars

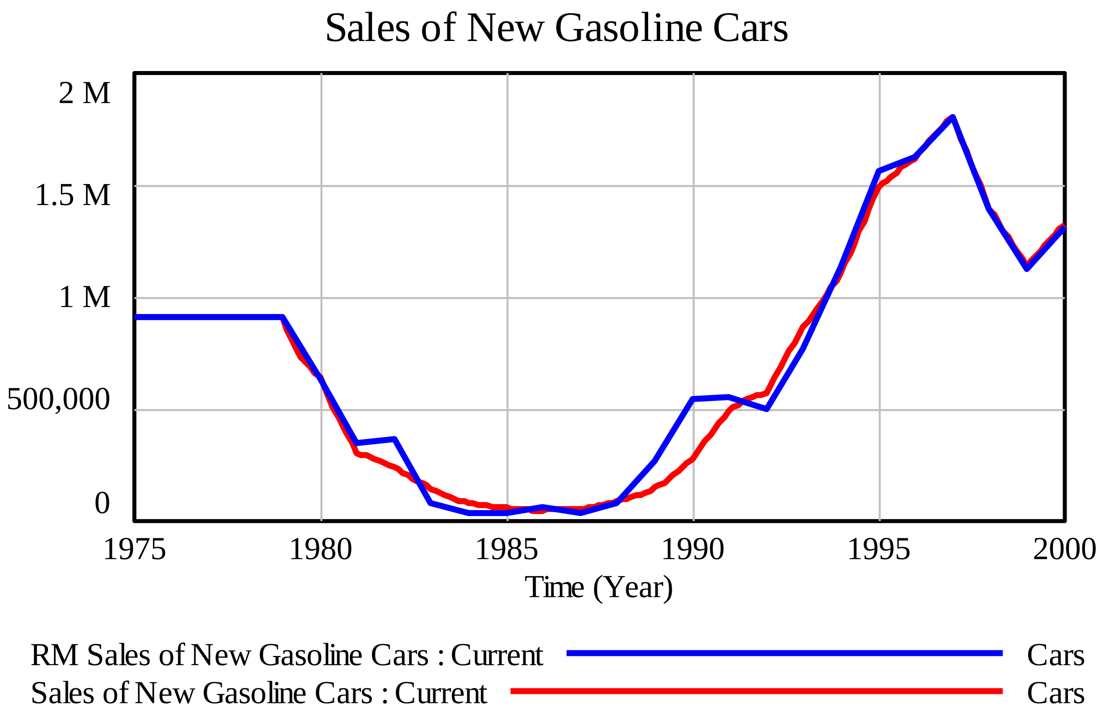

Figure 18 - Sales of New Gasoline Cars

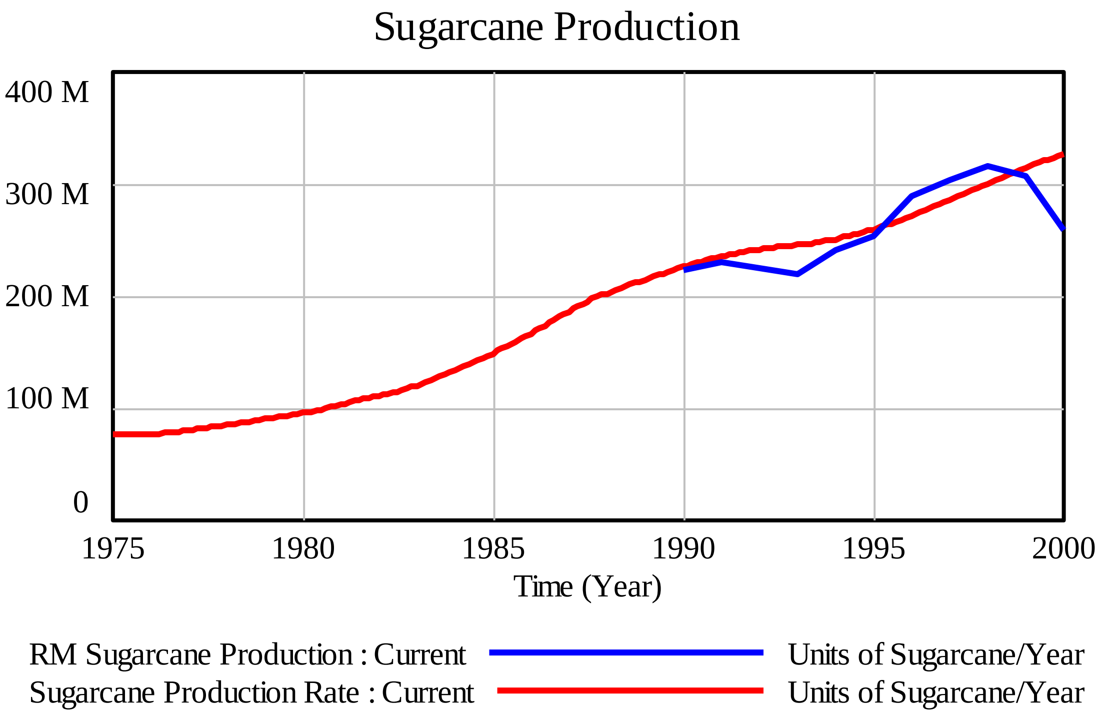

Figure 19 - Sugarcane Production

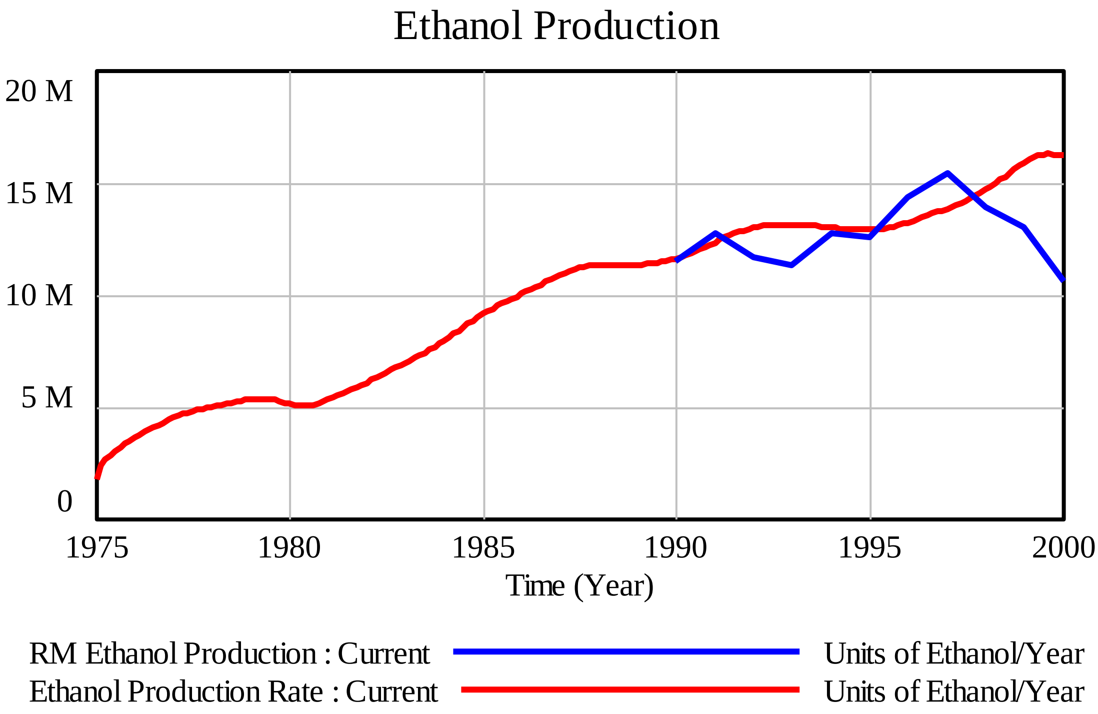

Figure 20 - Ethanol Production

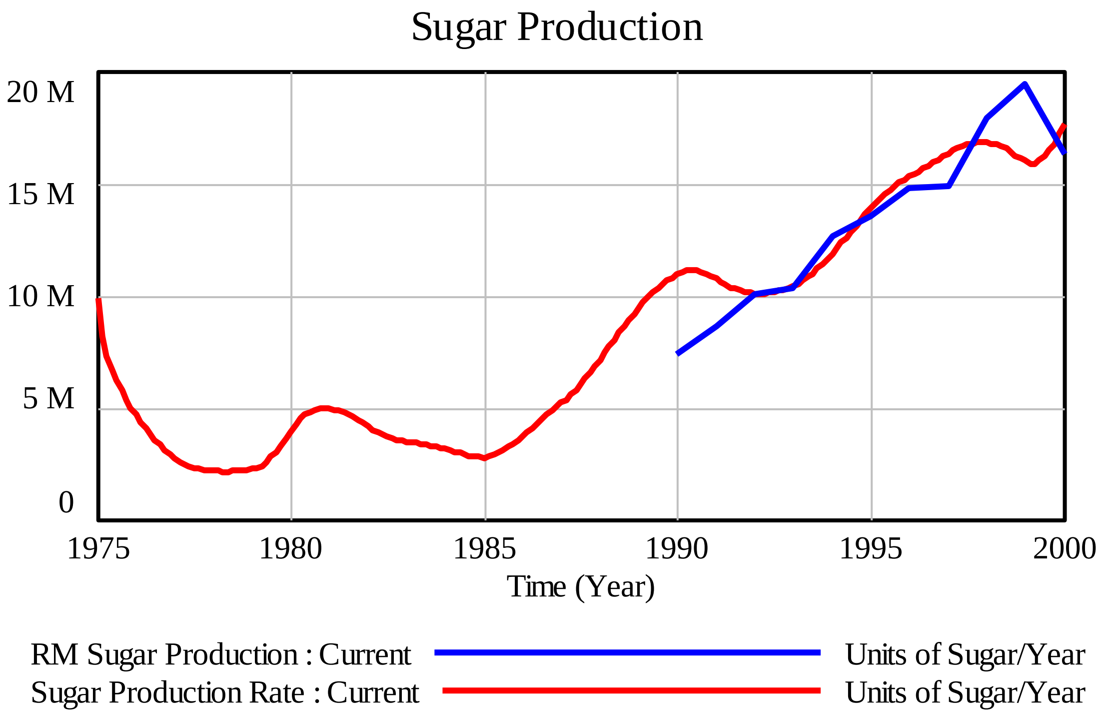

Figure 21 - Sugar Production

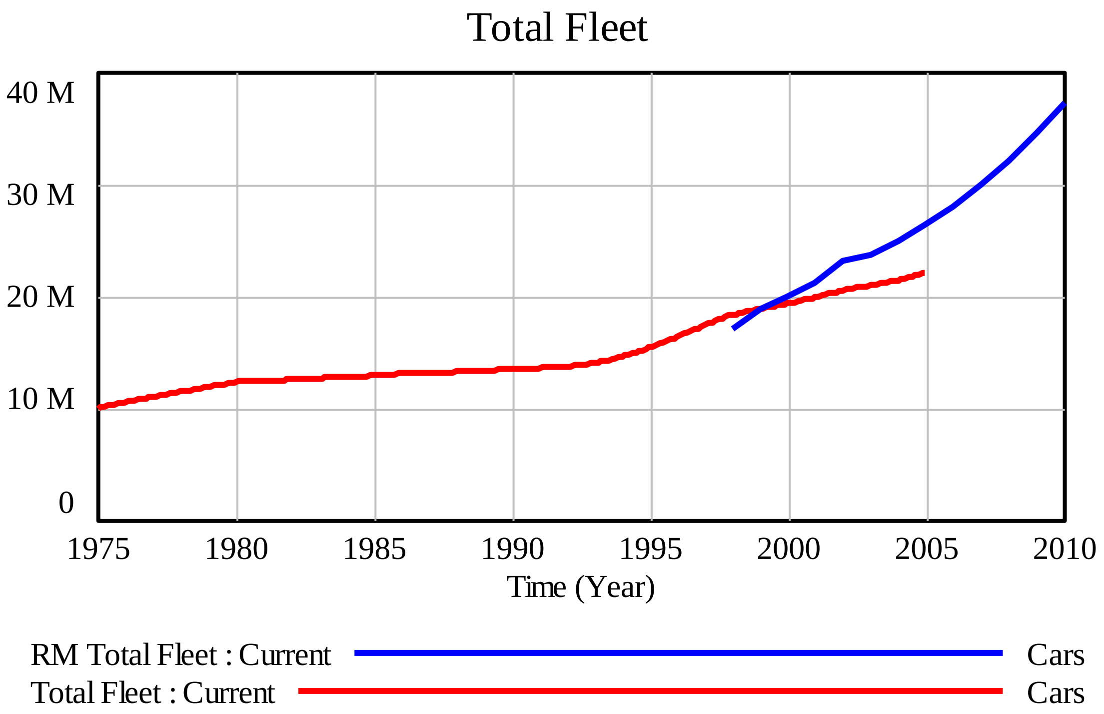

Figure 22 - Total Fleet

Considering the sales of new vehicles (ethanol and gasoline), the model shows a behavior considered appropriate. After 1987, there is small shift in phase in *Sales of New Ethanol Cars*, but with minor effect in results. Sales of New Gasoline Cars behave very close to the Reference Mode, except for some sudden changes in sales (1981-1982 and 1990-1992).

Other BOT[9] graphics just show that despite the *Initial Time* of simulation started at least 15 years before the first available data, the model behaved with a proper order of magnitude.

Exploring the model

Figure 23 show the behavior of the model for Capital, Desired Capital and Capital Utilization, for the Base Case. It can be observed that after 1985 there is a smooth decline in Capital Utilization. It is consistent with our perception of what really happens in the industry. As the fleet of cars to ethanol consisted of car E100, users had no option to change the fuel and ethanol demand decreased steadily and smoothly, as the ethanol fleet decreased for obsolescence. Despite the problems the industry experienced, it survived till 2003, when the flex fuel technology was launched.

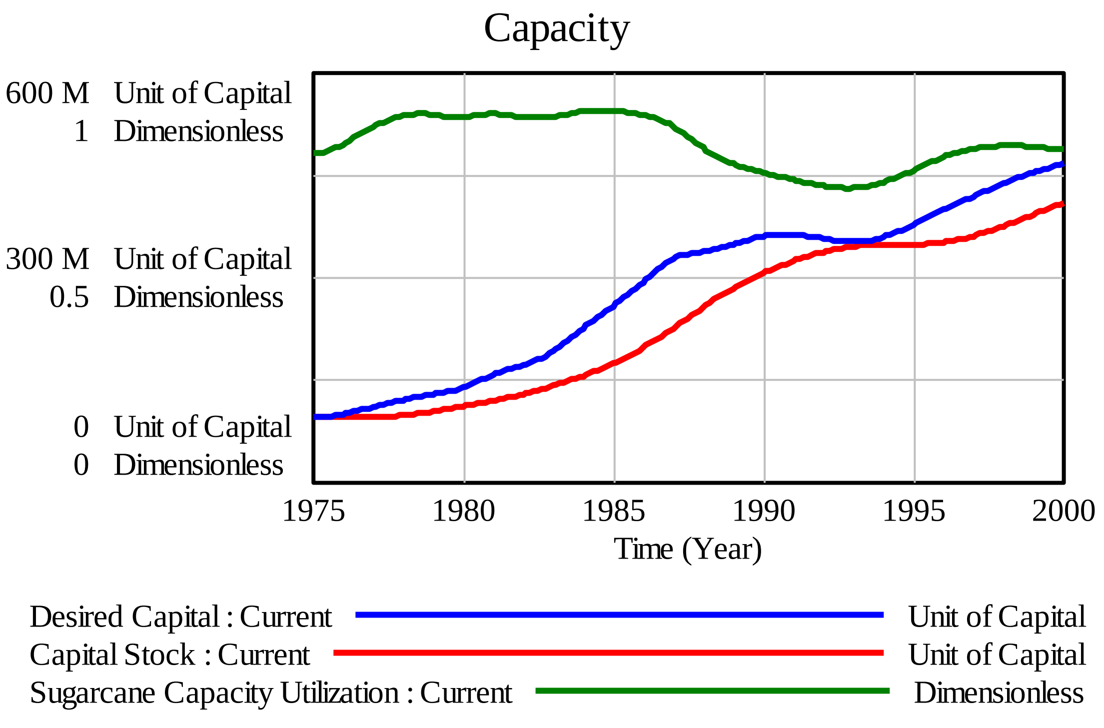

Figure 23 - Capital, Desired Capital and Utilization (Base Case)

---

[9] BOT = Behavior Over Time

Figure 24 illustrates a hypothetical situation: a situation where users can choose not to use ethanol. Assuming that in 1985 the Government taxed the ethanol production, and that users had the option to use other type of fuel in their cars[10].

The region highlighted by the red ellipse highlights a result of consumer choice. Despite the model is not fully calibrated, it can be observed that Capital Utilization decreases abruptly from around 85% to 50%, and remains there for approximately three years, growing very slowly after 1989.

Naturally, this would lead to a collapse of the industry, not represented in the model, due to model limitations. But it is possible to predict its social and economic effects: high unemployment rate, decrease in the economic activity, disorder in the sugarcane sector, and possible social chaos in the countryside..

None of these effects are desirable and must be taken into account when evaluating a high level decision of cutting subsidies and/or surtax one sector in economy. The side effects of the purposed action can be unacceptable leading to undesirable consequences.

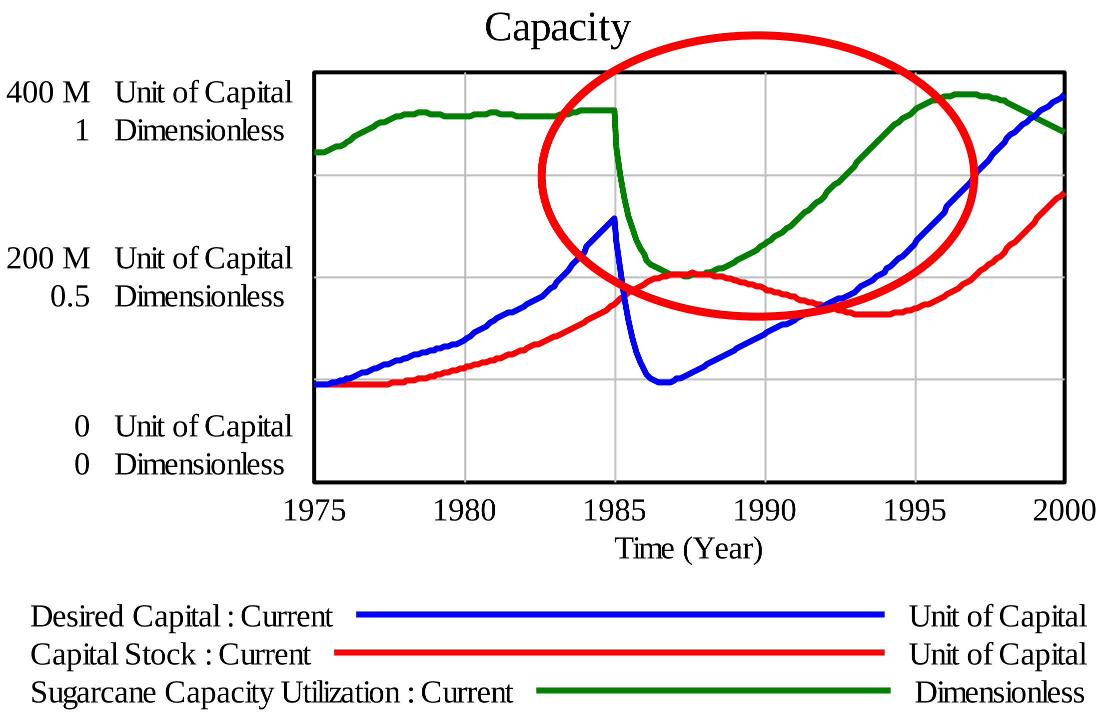

Figure 24 - Capital, Desired Capital and Utilization (Abrupt Change in Demand)

---

[10] In this model it is not possible, but it could happen with flex-fuel technolgy. Users could indeed change from ethanol to gasoline in a very short period of time.

Conclusions

This article began with a brief review of literature where various authors presentobstacles to the programs for biofuel. As a counter point to these authors present the views of some Brazilian scientists and Sugarcane Industry Association (UNICA). After this brief literature review a short description of the sugarcane industry in Brazil was presented, emphasizing the ethanol industry from 1975 to 2000, period of study.

To make the system visible, a causal loop diagram of the system was presented e explained. After that a preliminary model, with 141 equations, was discussed. The results obtained from the model behavior permit to conclude that model behaves qualitatively similar to the sugarcane industry in Brazil, from 1975 to 2000.

Next step was to investigate the consequences of some suggested policies by some authors to taxing biofuels, or even ban them. To do so a particular simulation was run, with hypothetical assumptions:

a. It was assumed that users of ethanol-powered cars could somehow instantaneously choose to use another type of fuel, and
b. Suddenly, there was a severe reduction in ethanol consumption in the model caused by a sharp drop in demand.

The results obtained by simulation show important side effects of the suggested policies. The first and most visible is the sharp reduction in capacity utilization of industry. The other consequences, less visible, are the effects of underuse: high unemployment rate in the industry with relevant social and economic consequences. Sugarcane industry would also behave unsteadily with oscillations. This would also bring consequences in the long-term.

The short and long-term consequences described above are not desirable and should be taken into account. They are not a demand of a stakeholder with monetary objectives; that is also a question of employment with relevant social and economic consequences such as: high unemployment rate, decrease in the economic activity, disorder in the sugarcane sector, and possible social chaos in the countryside.

Acknowledgments

Acknowledgements will be included in final version of the paper.

References

Goldemberg, José. "Ethanol for a sustainable energy future." *Science Magazine*, 2007, 315 ed.: 808.

Goldemberg, José, and Patricia Guardabassi. "Are biofuels a feasible option?" *Energy Police*, 2009: 10 -14.

Laurence, W. F. "Switch to corn promotes Amazon deforestation." *Science Magazine*, 2007, 318 ed.: 17 - 21.

Leite, Antonio D. *A Energia no Brasil.* Rio de Janeiro: Elsevier Editora, Ltda., 2007.

Moreira, J.R., J. R., and José Goldemberg. "The alcohol program." *Energy Policy*, 1999.

Sandvik, Sven. "Impacts of Peak Oil and Food Based Biofuel Production on Long-Term Food Security." Dissertação de Mestrado, Geografia, Universidade de Bergen, Bergen, 2008, 57.

Sandvik, Sven, and Erling Moxnes. "Peak Oil, Biofuels and Long-Term Food Security." Edited by System Dynamics Society. *27th International Conference of the System Dynamics Society.* Albuquerque, NM, 2009.

Silbiger, Steven Alan. *The ten day MBA.* 3rd. New York, New York: HapperCollins Publications, 2005.

Sterman, John D. *Business Dynamics: System Thinking and Modeling for a Complex World.* New York: Irwin McGraw-Hill, 2000.

Sugarcane Industry Association. 2011. http://english.unica.com.br/ (accessed 03 21, 2011).

Zah, Rainer, Heinz Boni, Marcel Guach, Roland Hischier, Martin Lehmann, and Patrick Wager. "Life Cycle Assessment of Energy Products: Enviromental Impact Assessment of Biofuels - Executive Summary." 2007.

Ziegler, J. "Draft reports on the special rappoteur on the Right to Food to the General Assembly, 62/2007T." United Nations Organization, 2007.