The Brazilian ethanol industry: an overview of its production, technology, location, land use, regulations, and future prospects

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Abstract

Brazilian ethanol has been used as biofuel since the 1970s, and currently is replacing approximately 40% of the gasoline that would be otherwise consumed in the country. Domestic demand for Brazilian ethanol is increasing as well as its exports since the biofuels are being promoted by governments around the world as an alternative to fossil fuel. In this context, the main objective of this paper is to do a descriptive and exploratory analysis of the Brazilian ethanol production system and the potential of biofuels in Brazil. We overview the recent developments in the ethanol industry with regard to ethanol technologies in Brazil (including new varieties, transgenic varieties, cellulosic technology), and the role of the Brazilian Agricultural Research Corporation (EMBRAPA) research in this area. We examine the government promoting policies and their impacts on land use such as the increase across time and
space in sugar cane area planted in the states of São Paulo, Paraná, Minas Gerais, Goiás and Mato Grosso do Sul (the main producers) and its consequences for other crops in these producing areas and for food security.

Key words: biofuels, ethanol, technology, land use.

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1. Emergence of Biofuels

The technological process to produce ethanol has been known for a century. However, the incentives to commercially produce the fuel took place starting in the 1970's. That was the time of the first oil crisis (Fig.1), and high oil prices along with low sugar prices provided both the political and economic reasons to stimulate the develop of the ethanol industry in Brazil and in the United States. In 1974, the U.S. Congress started to work on legislation to promote ethanol (Runge & Senauer, 2007). In 1975, the Brazilian National Ethanol Program ("Programa Nacional do Álcool, Proalcool") was created. In the former case, the main feedstock is corn, and in the latter it is sugarcane.

<Figure 1>

While in the U.S. ethanol production and consumption did not increase substantially from 1970's to 1990's, in Brazil, production increased from 0.60 billion m^3, in 1975/76, to 11.9 billion m^3, in 1985(Figure 2). This increase was a consequence of the Proalcool program that provided incentives to alcohol producers, such as agricultural and industrial financing, product acquisition guaranteed by the Sugar and Alcohol Institute (Instituto do Açúcar e do Álcool - IAA) and incentives to consumers through guaranteeing a maximum selling price equivalent to 66% of gasoline prices, and decreasing taxes that affected consumers (Moraes, 2006).. However, in 1986, oil prices started to decline, and the Brazilian government was not able to maintain its support to the sector, loans for increasing capacity were suspended and an increase in international sugar prices shifted the incentives toward declining production of ethanol in Brazil. During this time ethanol disappeared from the gas stations and this led to a deterioration of consumer confidence in the Proalcool program (Matsuoka et al., 2009).

<Figure 2>

A second worldwide resurgence of ethanol interest took place in the mid 2000's. Economic and political drivers were obviously important, since rapid growth in oil prices was occurring (Fig.1). Additionally, biofuels were held in high regard, as they were renewable, and some exhibited large energy efficiencies and had low costs, such as the sugarcane in Brazil, thus offering a clean energy alternative for the reduction of greenhouse gas emissions from transport (Mueller & Martha, 2011). New policies were then put in place to encourage biofuels production globally. In the case of Brazil, in particular, a technology breakthrough – the development and spread of flex-fuels light vehicles starting 2003 – was especially important. It allows the vehicle to work with ethanol mixtures from 0 to 100% and was a major reason boosting the resurgence interest for the industry in the country. As a result, in 2010, 86% of new light-vehicles sold were flex fuel (Anfavea, 2011).

However, some concerns regarding biofuels arose in mid 2000's. On the one hand, the fuel versus food debate sustained that biofuel production was impacting food/feed prices and hence could jeopardize food security especially in poor countries that depend heavily on food imports. On the other hand, negative environmental issues associated with biofuel production, mainly related to indirect land use changes, were raised.

The indirect land-use effect would result firstly from the displacement of an agricultural activity by biofuels crops and then those displaced activities would eventually be reallocated to the agricultural frontier pressuring native vegetation. According to La Rovere et al. (2011), the area used to increase sugarcane production has mainly replaced pasture lands, without harming staple food production. Marginal lands and degraded pasture areas would be interesting areas to accommodate the expansion of food and biofuel area with low environmental costs. This would be a win-win situation in that food/feed and biofuel production would be increased without the need of further deforestation at the same time low-productivity agricultural areas, mainly pastures, would be replaced by more efficient uses (Martha, 2008).

The increase in agricultural production can be achieved through the expansion of the cultivated area, the increase in productivity or, more frequently, a combination of both. A major concern in Brazil and abroad, is the possibility of expanding future biofuel production through mainly, and if possible, exclusively, yield gains. In this context we will review policies and technologies and the literature to observe what are the future prospects of biofuels in Brazil and its consequences around the world.

The objective of this study is to assess the impact Brazil´s

- fuels policies
- possible environmental and land policies
- new technology based on public and private research

On

- production of ethanol and prices, production and trade of major commodities in Brazil and
- prices, production and trade for the rest of the world, including poor developing countries.

The paper is structured as follows. In section 2 we describe some of the major current government policies and potential policies – both fuel policies and environmental/land use policies - that influence biofuel production in Brazil. In section 3 we look at some of technological changes that could be expected in the next several decades which could affect the productivity of ethanol production as well as the elasticity of substitution between ethanol and gasoline in Brazil. Section 4 starts with a description of previous studies that have looked at the impact of biofuel on Brazil and the world. The second part of the section describes our approach and how we will assess the policies and technological progress we describe in 3. Section 5 presents the results of our simulations which show the impact of these policies on prices and production in Brazil and on the world. Section 6 presents the implications of our studies for Brazilian scientists and policy makers and for world markets.

2. Description of policies and technologies for ethanol and biodiesel in Brazil

Since the beginning of the XX century Brazilian government has supported the ethanol industry, through creating institutions such as Instituto do Açúcar e do Álcool (IAA), through launching the Proalcool program, which was important to the development of the industry, through investing in research by Instituto Agronômico de Campinas (IAC) and FAPESP (São Paulo state Research foundation) and by Planalsucar a federal government program that was created in 1971 with a particular focus on the development of new sugarcane varieties. Government's current role is different and smaller compared to the past (Martines-filho et al. , 2006), in the next section we will review the current policies that are in place, followed by a review of the government and private research funding.

2.1. Ethanol policies

Blending mandate

Since 1993 the ethanol blend to gasoline is allowed to change within the 20-25% range depending on the ethanol market. As an example of how the mandate has changed in recent years, from 2003 to 2006 the blending remained as 25%, however, ethanol shortages and rising prices in March 2006 caused the government to relax the mandate to 20%. By the end of 2006 the government increased the blend to 23% and in June 2007 restored it to 25%. In 2010, a rainy season and a decrease in sugar cane crushing caused a shortage of ethanol and as a result the government decreased the ethanol blend to 20%, when the crop season started, in May 2010, the 25% mandate was reestablished.

Taxes incentives and import tariff

In addition to the ethanol mandate, there are some tax incentives through CIDE *Combustíveis* and PIS/COFINS. CIDE *Combustíveis* (Contribution for Intervention in Economic Domain for fuels) is a contribution levied on the import and sale of oil and gas-related products including ethanol. According to the law, the tax collected should be used for three purposes: to pay subsidies on prices or transportation of ethanol, natural gas, oil and their derivates; to finance environmental projects related to oil and gas industries; and to finance infrastructure programs for transportation. Even though CIDE is also applied to ethanol, since May 2004 it has been fixed at zero (Moraes, 2006). For gasoline, CIDE is charged on producers and importers and its value changed through time. In 2004 it was set at R$ 0.28/liter, in May 2008 changed to R$ 0.18/liter, to prevent the increase in oil prices to be transferred to consumers. In June 2009, the value increased to R$ 0.23/liter, in February 2010, with the reduction of ethanol content in the gasoline blend, CIDE was reduced to R$ 0.15/liter to avoid an increase in gasoline prices. Since May 2010 CIDE was restored to R$ 0.23/liter, which in the first week of April 2011, using gasoline prices in Brasilia, is equivalent to an 8% tax (Secretariat of the Federal Revenue of Brazil, 2011a).

PIS/COFINS (Contribution to the Social Integration Program/Contribution for Financing Social Security) federal taxes are charged together. For gasoline, a cumulative fixed assessment of 9.25% is charged to the manufacturer upon sale to distributors. For ethanol, a contribution value of R$ 0.12/liter is charged for PIS/COFINS (R$ 0.048/liter on producers and R$ 0.072/liter on distributors) (Secretariat of the Federal Revenue of Brazil, 2011b).

ICMS is a State tax for services and goods circulation. For ethanol ICMS varies from 12% to 30% with most states charging 25%. For gasoline ICMS varies from 25% to 31%. The state of São Paulo has a 12% rate for ethanol and 25% for gasoline, which makes ethanol economically competitive with gasoline compared to other states. As a comparison, Table 1 shows tax differences between gasoline and ethanol in São Paulo state for 2009.

Table 1 - Gasoline and Ethanol Prices and Taxes in 2009 – São Paulo state

	Gasoline C	(%)	Ethanol	(%)
Consumer prices	2.384		1.336	
ICMS	0.596	25%	0.16032	12%
CIDE	0.205*	8.6%	0	0%
PIS/COFINS	0.22052	9.25%	0.12	8,9%
Total Taxes	1.02152	42.85%	0.28032	20.98%

Source: ANP 2010.

* CIDE for gasoline was equivalent to R$0.18/liter until June 2009 and then changed to R$ 0.15/liter. I

used an average of both numbers.

Another incentive to the ethanol sector is that the IPI tax, applied whenever a new car is purchased. It is lower for ethanol fueled cars than for gasoline fueled cars. Table 1 shows the differences of taxes that also vary according to the power of the engine.

<Table 1>

For the 2009/2010 season a subsidy for sugarcane farmers and cooperatives from the Northeast was put in place to compensate for the difference in costs of production difference between the Northeast and the Southeast and South regions. Ministers of Agriculture and Finance established that Northeast sugarcane farmers and cooperatives would receive R$ 5.00 per ton of sugarcane sold between August 1, 2009 and July 31, 2010. The limit was 10,000 tons per farmer or cooperative and the National Company of Food Supply (CONAB) was responsible for the payments to producers.

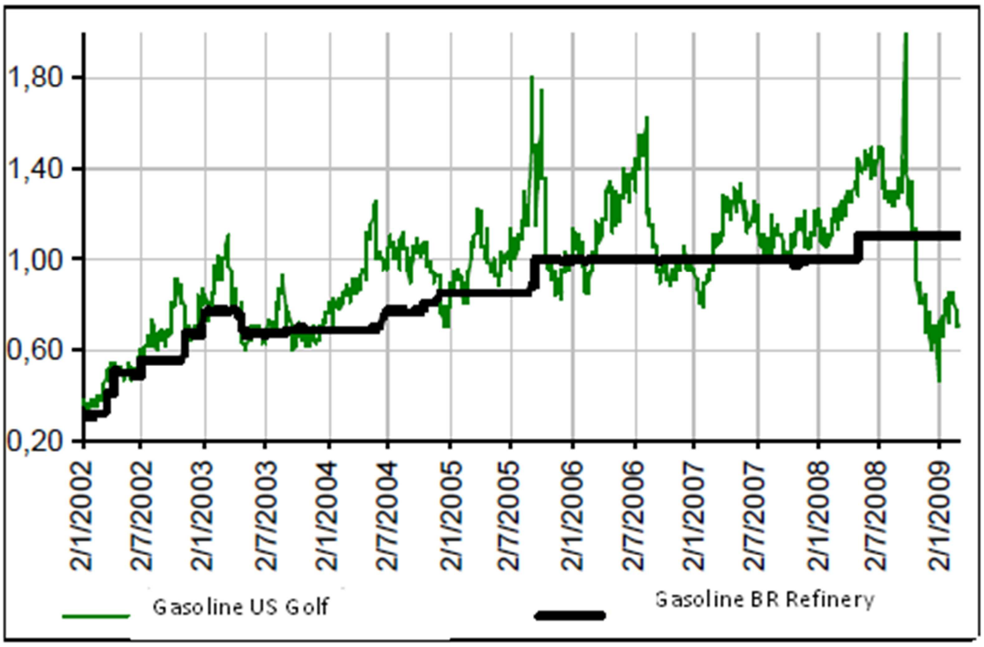
Even though there was a 20% import tariff applied to ethanol imports, in April 2010, The Brazilian Chamber of Foreign Trade (CAMEX) passed a Resolution that eliminated the tariff from April 2010 to December 2011. The Brazilian Sugar Cane Industry Association - UNICA welcomed this resolution, because they believe this will strengthen the discussion about opening other markets, mainly the U.S ., which is important to expand the use of ethanol in the world and to transform it into an energy commodity (UNICA, 2010). Besides, in periods that sugar prices are high and Brazilian producers are using their sugarcane to produce sugar, such as in 2011, UNICA can import ethanol from the US to protect against shortages.

Petrobras Pricing

Consumer gasoline prices (called gasoline “C”) depend on the following five components: gasoline “A” prices, which is the gasoline that Petrobras sells to refiners, anhydrous ethanol prices that have to be blended into gasoline, distribution costs, and taxes (Petrobras, 2011). In the case of Petrobras gasoline “A” pricing, they do not adjust prices every time that there are changes in international oil prices, as a matter of fact the last time that they adjusted prices was in 2009. According to an official press note, prices are adjusted whenever oil prices in international markets reach a certain (stable) level, the government wants to avoid transferring the short term volatility of oil prices in international markets to Brazilian consumers. Through this pricing policy they believe that in the long run prices are still coordinated with key international competitors and Brazilian consumer is protected from extreme volatility of the international derivatives market, which reflects often geopolitical conflicts, weather and others (Portal Brasil, 2011).

Figure??? Shows a comparison between Petrobras prices and US golf prices.

Figure ??? – Gasoline Prices (R$/liter)



Source: Tendências Consultancy (2009).

Once Petrobras has fixed the price of gasoline "A" market forces (costs of ethanol production, transportation, demand, etc.) plus taxes determine the prices of ethanol and gasoline C.

Credit

The National Bank for Social and Economic Development (BNDES) is the main government institution that provides credit lines to fund renewable energy investments. There are specific programs such as FINAME that is exclusively for financing the agriculture sector to buy new machinery and equipment; FINEM is used to carry out projects for implementing, expanding and modernizing; MODERFROTA is used to acquire agricultural tractors and related implements and harvesters; MODERMAQ is used to finance the purchase of capital goods, FUNTEC is used to support technological development and innovation in strategic areas, PROINFA is used to finance power generation from alternative sources. BNDES created a program called PASS, which is a credit line of R$ 2.4 billion at a 9 percent/year interest rate to create ethanol stocks. As a comparison, Table 2 shows 2010 interest rates for firms and consumers in Brazil.

<Table 2>

Institution	Interest Rate for a R$ 50,000.00 Investment
BNDES	8.73%

Caixa Econômica Federal	12.01%
Banco do Brasil	12.55%

Source: FIESP - São Paulo State Industries Federation

In March 2011 BNDES and FINEP, which is an institution from the Ministry of Science and Technology that finances research and projects, signed a technical cooperation agreement for implementing a Plan to Support Technological Innovation in the Sugar and Ethanol Industries (PAISS). This new program will have available R$ 1 billion to lend to private firms or to government research institutes research for the period 2011-2014.The main goal is to promote projects that intend to develop, produce and commercialize new technologies for the industrial processing of biomass from sugarcane into ethanol. There are three thematic lines in this program: 2nd generation Bioethanol; new sugarcane products, including development from sugarcane biomass by biotechnological processes; and gasification, with emphasis on technologies, equipment, processes and catalysts. Depending on the case the government support could be a loan, research grant, or economic subvention. (BNDE-PAISS, 2011).

The agreement between BNDES and FINEP for the creation of PAISS also aims to stimulate the production of higher added value products, which can be obtained from sugarcane biomass, for example, higher energy content of fuels (diesel, gasoline, jet fuel) or even intermediate chemicals with multiple industrial applications. Figure 3 shows the amount of BNDES investments in the sugar ethanol industry since 2004.

<Figure 3>

In February 2011, the Brazilian President Dilma Rousssef met with the Ministers of Agriculture, Economics and Energy and required a National Plan for the Sugar and Ethanol Sector in order to give incentives to increase investments in the sector and to increase the production of ethanol. The Ministry of Agriculture said he had been holding meetings with all the sugarcane supply chain, among them leading companies in the industry - Copersucar, Cosan, Bunge and Louis Dreyfus Commodities - and they identified the interruption of investments between 2008 and 2009 as the bottleneck that created the current ethanol supply shortage. At that time, the sector came from two years of low prices for sugar and ethanol and was one of the hardest hit by the world crisis. As a result, projects to build new plants have been suspended or abandoned and recent investments have been directed to expand the supply of sugar, whose prices are the highest in 30 years.

Environment

A Federal environmental law approved in 1998 established a gradual elimination of burning the sugarcane straw in areas with slopes less than 12% where mechanization is possible and mechanization will become mandatory by 2018. The federal legislation did not have a schedule for areas with more than 12% slope. In 2000, a São Paulo state law was approved and it was determined that by 2021 sugarcane burning will be prohibited in areas where mechanization is possible (slopes lower than 12%) and by 2031 sugarcane burning will be prohibited in areas where mechanization is not possible (slopes higher than 12%). This law also determined specific areas where sugarcane burning is categorically prohibited such as one kilometer of the perimeter of urban areas, 100 meters from the boundary of electric power areas, 50 meters around the boundaries of preserved areas, twenty five meters around the boundaries of telecommunications stations areas, fifteen meters along the boundaries of energy transmission and distribution lines, fifteen meters along the boundary of railways and federal and state highways areas. In 2007, the São Paulo State Government and UNICA signed an Agricultural and environmental Protocol for the sugar/ethanol industry that anticipates to 2014 the end of sugarcane burning with slopes lower than 12% and to 2017 for hilly areas. In 2008, the Minas Gerais State Government and SIAMIG/SINDAÇÚCAR (Sugar and Energy Industries Association and Union) also signed an elimination intention of burning sugarcane in the ethanol/sugar sector and they compromise to end the sugarcane burning by 2014.

Besides the burning legislation, there are also regulations and the need of an environmental license for ethanol distilleries, sugar plants and units of production of spirits before they start to operate.

Some environmentalists outside of Brazil seem argue that Brazil should not allow the expansion of sugarcane production onto new lands or onto current crop lands and pastures because of its direct or indirect impact on land use and GHG emissions. The government’s response to these concerns has been to restrict sugarcane production to certain regions where they will have limited or no impact on GHG emissions and biodiversity.

In 2009, President Lula approved a Decree to conduct a Sugarcane Agro-Ecological Zoning (known as 'ZAE Cana' in Portuguese) in order to establish rules for the sustainable expansion of sugarcane harvesting for sugar and ethanol production in Brazil. The zoning determines the most suitable areas as well as the most appropriate period of the year for planting to avoid losses due to weather adversities. To make the mapping of the national territory, the following guidelines were set: exclusion of areas with native vegetation; exclusion of areas for cultivation in the Amazon and Pantanal biomes, and in the Upper Paraguay River Basin; identification of areas with agricultural potential without need of full irrigation; identification of areas with slope below 12%; respect for food security and prioritization of degraded areas or pasture (Sugarcane Agro-Ecological Zoning, 2009). As a result of the rules, it is possible to use only7.5% of Brazilian lands to plant sugarcane, the other 92.5% of the territory is not suitable. These rules will be used by financial agents to provide credit to the sector (Figure 4).

<Figure 4>

2.2. Biodiesel policies

The Brazilian National Biodiesel Production Program

In July 2003 the Brazilian President created, through a Presidential Decree, an interministerial working group to study the possibility of using biodiesel as an alternative energy fuel. As a result, in 2004, the Brazilian National Biodiesel Production and Use Program - PNPB was created with the main objective of promoting the sustainable production and use of biodiesel focusing in social inclusion and regional development. To create employment and income for family farmers in rural areas, the Ministry of Agrarian Development created a "Social Fuel Stamp" for producers buying raw material from family agricultural business. Through this certification, biodiesel producers are able to benefit from lower federal taxes, which vary according to region and crops In order to get the social fuel stamp, biofuels producers are required to buy a minimum amount of raw materials that will vary according to the region. In the Center-West and North regions they must buy at least 15% of raw materials from family farmers. In the Northeast, South and Southeast they must buy at least 30% of its raw materials from family farmers.

After getting the social stamp the tax exemption will also change according to the region and according to the raw material as described in the following Table 3. Notice that biodiesel producers that buy from PRONAF farmers get a bigger benefit. PRONAF is the National Program for Family Farmers to provide rural credit; this program includes 15 classifications (and interest rates will be different) that vary according to income, gender, age, farm activity, purpose of credit and location. However, to qualify for this program farmers have to fulfill at least the following criteria: i) family workers with a maximum of two hired workers; ii) family income between R$6,000.00 and R$ 110,000.00 iii) the size of the farmland should not exceed four "fiscal modules" and iv) they need to live in the land property or nearby.

<Table 3>

Besides the reduction of PIS/PASEP, a contribution for the social integration program, and COFINS, a contribution for financing social security, the Industrialized Products Tax - IPI, which is the tax applied on all industrialized products, is zero for biodiesel.

When the National Agency for Petroleum, Gas and Biofuels - ANP issued regulations regarding biodiesel specifications and regulations to organize the productive sector, there was uncertainty about whether the country industry would or not be able to develop the production capacity and processing of raw material to meet the demand generated by the regulation. The original schedule established that: in 2005 a 2% biodiesel addition would be optional, in 2008, a 2% biodiesel addition would be mandatory and finally, in 2013, a 5% biodiesel addition would be mandatory. However, the biodiesel industry was able to respond and the original schedule was changed, in July of 2008, a 3% biodiesel addition became mandatory, in July of 2009, a 4% biodiesel addition became mandatory and, in January 2010, a 5% biodiesel addition became mandatory, as a result the regulation was entirely applied three years before schedule.

According to a recent research from Getulio Vargas Foundation (FGV, 2010), the biodiesel industry is still in expansion, which will allow more biodiesel production and a possible increase in the mandate blend. The production capacity is currently approximately 5.1 million m^3, exceeding the demand generated by B5 and very close to the projected demand for a possible B10 in 2014 - and there is an expectation to increase further with the implementation of projects currently in progress. This research also presented the benefits of the "Social Fuel Stamp" program for family farmers. Currently, 20% of all biodiesel produced comes from family farmers, and 90% this volume produced used soybeans. They estimated that when considering only the biodiesel soybean complex, 1.6 million jobs were created. Soybean is still the main raw material used for biodiesel production, responsible for 78% of the production, beef tallow, cotton oil and others participations are 16%, 3% and 3%, respectively. Further, they believe that diversifying raw materials use, for example by using perennials crops, would result in more employment, income and would help with regional development. Many oilseeds such as cotton, oil palm, castor beans, peanuts, sunflower, among others, have potential for the production of biodiesel, however, the challenge is to be able to develop technologies to produce them.

Biodiesel in the Amazon

Besides the prospect of producing biofuels from different oilseeds, and the possibility of family farmers to increase their income through biofuels production, another important expectation was to be able to produce biodiesel for energy sustainability in the legal Amazon area (this area includes forest and cerrado biomes). According to the Amazon State PNPB program, "the inclusion of Amazonas State in the PNPB means that we can strive for the dream of self-sustainable energy production in our state´s 61 hinterland towns since, according to the state version of the Program, each town should produce enough power to supply its own needs.” (Regional and State Initiatives – Biodiesel National Program Production Program).

A study by Andrade and Miccolis (2010) analyses government and private sector strategic policies as well as the different perspectives on the obstacles and advantages of implementing biofuels policies in the Amazon. The authors agree that there is potential for biodiesel production in the Amazon, however, they consider that social and environmental safeguards have to be put in place. The main concerns are: contracts between family farmers and biodiesel producers that do not allow intercropping species, which might affect food security for the population; to ensure that crop system established, especially for the case of palm oil, will use degraded areas and that they will be implemented preserving biodiversity. Among the raw materials used for biodiesel production, oil palm is considered as the main alternative due to its low production costs, high potential for creating jobs and income and possibility of using degraded areas. It is possible to use other palm species for biofuel production but they still require research,

Finally, it is important to highlight that even in the Amazon soybean is the main raw material for biodiesel production; this shows that the challenge is to put enough incentives in place to encourage the use of other crops for biodiesel production.

3. Government and private funding of research

In the last decade there have been major investments in biofuels research and development by the Brazilian government. One recent article in Science (Regalado, 2010) estimates that total biofuel research by Brazilian governments has grown by some 500% during the past decade and now totals about $90 million per year (Science 2010) A more recent estimate by Dr.Marcos Bucheridge head of CTBE is that R&D expenditure could be $150 million on biofuel (Personal communication August 2010)

3.1. Plant Breeding and Biotechnology

The government of Brazil and state governments have been involved in sugarcane research and breeding since well before World War II. The Institute of Agronomy at Campinas (IAC) financed by the State of Sao Paulo was responsible for many sugarcane varieties that were developed and grown before and after World War II (Furtado et al., 2011).

In 1970 the government of Brazil established Planalsucar, a federal financed sugarcane breeding program, at the Instituto do Acucar e do Alcool (IAA). When ProAlcool was started it supported the IAA breeding programs. In 1990 the IAA research program was dismantled. The IAA scientists and facilities were distributed to seven federal universities and renamed Ridesa (Rede Interuniversitária Para O Desenvolvimento Do Setor Sucroalcooleiro). Since then two more universities have been added plus several experiment stations on the Cerrado. More than half of the sugarcane area was planted with Ridesa varieties in 2007 (Ridesa website)

The other major sugarcane breeding program is at Centro de Tecnologia Canavieira (CTC) which is funded by the sugar and ethanol mills. The varieties that they developed cover most of the area that is not covered by Ridesa varieties.

FAPESP funded a major effort to sequence the entire sugarcane genome starting in 1999 and then supported functional genomics research to understand the genetic basis of yield, pest resistance and response to climate change. Then in 2008 they financed the Research Program on Bioenergy (BIOEN) which includes a major component on sugarcane, including plant improvement and farming.

Sugarcane yields are likely to continue to grow in the near future because of major public and private investments have been made on sugarcane. Private biotech firms have made many new investments in biofuel R&D recently. The first private firms outside of CTC to conduct research on sugarcane breeding and biotech were CanaVialis and Alellyx which were developed in 2002 and 2003 by university faculty members who had worked at the Federal University of San Carlos and at the University of Campinas on sugarcane breeding and sugarcane biotechnology. They were both funded by the venture capital arm of Votorantim Group. After that most major multinational biotech firms have made substantial investments in sugarcane breeding and biotechnology. Monsanto made a major investment in sugarcane R&D by buying CanaVialis and Alellyx for $290 million (Monsanto, 2008). Together, these firms had been spending $32 million on sugarcane R&D in 2008 (BNDES & CGEE, 2008, p.165). Syngenta has been collaborating with the Queensland Institute of Technology (Australia), the Agronomy Institute of Campinas in Sao Paulo, Brazil, and several other organizations to develop technologies for cellulosic ethanol from sugarcane (Syngenta, 2007). In 2009, BASF also made a commitment to work on more efficient planting technologies and improving sugarcane yields and drought tolerance in Brazil (BASF, 2009).

Other parts of the public sector have also increased their investments in research recently. Ridesa is expanding its research program. EMBRAPA launched a major agroenergy research program in 2008 and opened a new branch called EMBRAPA Agroenergy, which long-run research agenda, for the period 2008-2023, includes three main objectives: to develop production systems and raw materials with superior characteristics for the production of energy; to study zoning and evaluation of environmental, economic and social impacts aiming to identify competitive and sustainable areas for producing bioenergy; and to develop bioenergy technologies and production systems to be used in degraded areas (Sundfeld, 2010).

The research agenda for the period 2008-2011 has two main focuses; one is the development of new technologies of energy (ethanol from cellulose, products of bio-refinery, hydrogen). Specifically there are three sections of this research, which are: to find the enzymatic pathway for ethanol from lignocellulosic materials; to investigate enzymes, fungi, bacteria and catalysts for energy production; and R&D focusing on the concept of bio-refinery. The second focus of the research agenda is the development of technologies using by-products and residues**,** more specifically, the use of meals, glycerin & by-products of biodiesel production; the use of by- products from the charcoal industry for the production of biofertilizers and biopesticides; and the use of residues and by-products from the 1st and 2nd generation ethanol production processes.

When looking specifically at sugarcane/ethanol research, currently there are around 100 scientists, from eight Embrapa R&D centers, two universities and one R&D institute, working to develop GMO´s for tolerance and resistance to biotic and abiotic stress; investigating biological fixation of nitrogen and modeling production systems. Moreover, other 75 scientists are working to develop technologies for a sustainable production of sugarcane for ethanol production in the state of Rio Grande do Sul. There are also around 75 scientists working for a project from Embrapa´s Cerrado Center that aims to identify different sources of biomass, among them residues such as bagasse, tips and sugarcane straw, for producing ethanol from lignocellulosic materials.

3.2. Conversion technology

In the past the technology to convert sugarcane into ethanol has mainly come from the private sector. Sugarmills have been able to increase their productivity, add co-products such as electricity, and reduce their costs of production by buying improved equipment from firms such as NG Metalúrgica and Dedini Indústrias de Base. In addition NG provides new equipment for generating electricity from bagasse which is becoming an important new byproduct of sugar and ethanol production. In addition CTC does a considerable amount of work on conversion technology and the logistics of sugarcane, sugar and ethanol production that have had a major impact on the efficiency of the industry. The sugar and ethanol mills themselves have achieved considerable efficiencies by increasing the size of their mills to obtain economies of scale.

The government supported industry investments to buy new technology through the Proalcool program and now through BNDES but did not invest much in research to develop these technologies until recently. Some research by the public sector has contributed to more efficient conversion technology. For example, research by University of Sao Paulo at Piracicaba is the basis for Fermentec's choice of yeasts to replace the baker's yeast that was the original yeast used in fermentation of sucrose to ethanol. Since 2001 FAPESP has funded CTC and Dedini to develop more efficient conversion processes.

In recent years BioEN, CBTE and EMBRAPA have all started investing in research to improve the efficiency of conversion technology and produce byproducts. For example BioEN has jointly financed research project with companies such as Dedini on improved processing technology for first and second generation biofuels, BRASKEM on green polymers, and Oxiteno on processing cellulosic materials.

3.3. Impact of Research

The impact of the sugarcane and conversion technology research over the last 30 years has been to increase efficiency dramatically and reduce the cost of producing ethanol (see Figure 5**).** It shows that both feedstock (sugarcane) and the cost of producing ethanol from sugarcane have declined.

<Figure 5>

The next figure (Figure 6) breaks down the reduction in cost of sugarcane production into its major components. Since 1975 costs declined due to increased yields (declining land cost), big reductions in soil preparation costs, reductions crop maintenance (pesticides, fertilizers) and harvesting and transportation.

<Figure 6>

The cost of ethanol production (excluding the cost of the feedstock) has declined because of reduced costs for capital and reducing variable input costs (Figure 7). Reduced investment costs were largely due to economies of scale but more efficient equipment also played a role. The decline in operational costs was due to factors such as improved factory management, more efficient yeasts, more efficient machinery, etc...

<Figure 7>

3.4. Cellulosic ethanol

Much of the new government money in biofuels has been focused on second generation cellulose based biofuels made from bagasse. The federal government in 2010 established the Bioethanol Science and Technology

Center (CTBE) a $40 million facility in Campinas, Sao Paulo state. The plan is to have 170 scientists & technicians by 2013. Its focus will be on cellulosic biofuel and they are hoping for an annual budget of $30 million/year for next five years.

FAPESP's BIOEN program funds 4 major programs in addition to sugarcane improvement:

1. Biorefinery technologies and alcohol chemistry
2. Ethanol applications for motor vehicles, motor cycle engines and fuel cells
3. Ethanol industrial technologies
4. The economics of ethanol, ethanol production and the environment, social impacts, the new agriculture of food AND energy.

The private sector is also making major new investments in biofuel production capacity and in improved conversion technology. Shell in their joint venture with Cosan is expected to bring in its in-house research and the research of its smaller partners Codexis and Iogen, which are among the leaders in research on converting biomass to biofuel. BP,which bought 50% of Tropical BioEnergia SA in 2008 and Companhia Nacional de Acucar e Alcool, or CNAA in 2011 will provide access to the research on cellulosic biofuel from the Energy Biosciences Institute at U.C.Berkeley, U. of Illinois, and Livermore National Laboratories, which is funded by BP.

Most experts in this field still feel that there will be little impact of cellulosic biofuel before about 2012 because that is how long it takes for industry build pilot plants, improve them and build the next set on plants, and finally go commercial in a really big way,

3.5. Drop In Biofuels – Sucrose to Diesel and Gasoline

The newest startup biofuel companies are focusing their research on developing processes that will convert sucrose or biomass into "drop-in biofuel," also known as green gasoline or green diesel (in Brazil it is called Canadiesel because it is made from sugarcane). These companies use engineered yeasts and bacteria to produce biofuel that are chemically identical to gasoline or diesel and therefore do not require blending with fossil fuels. Several of leaders in this field – Amyris, Codexis, and Gevo - have just gone public and report $82 million in R&D spending for 2009.

Recent discussions with scholars involved in the Energy Biosciences Institute at Berkeley who know the companies in this field suggests that the technology is ready to be implemented by about 2013 in one or more pilot industrial scale plants. Then as they learn from this plant, in another 4 years build a number of these plants and start to have a significant impact on the production of diesel and ethanol starting around 2017.

3.6. Expansion of the sugarcane area into the Cerrado

In the early 1970s EMBRAPA research on the management of Cerrado soils made them suitable for growing crops, first benefitted soybeans and corn but now sugarcane is starting to benefit from this knowledge as it moves into the cerrado. EMBRAPA at its Cerrado research center and Ridesa are now doing research to select appropriate sugarcane varieties and management practices for the cerrado.

Historical data shows the expansion of sugarcane in the cerrado biome, and according to previous studies (Nassar et al., 2008; Mueller and Martha, 2008) and to the Brazilian Ministry of Agriculture, Livestock and Food Supply (MAPA Agribusiness Projections, 2010), São Paulo, Paraná and the Center-West cerrados will continue to be the most important regions for sugarcane cultivation.

Observing the share of the states in the Brazilian production from 1996 to 2009 (Table 4), eight states were responsible for around 90% of the Brazilian sugarcane cultivated area: São Paulo, Minas Gerais, Paraná, Goiás, Alagoas, Pernambuco, Mato Grosso do Sul and Mato Grosso. Table 4 shows the state participation in the Brazilian sugarcane cultivated area. First, it is clear that São Paulo is responsible for more than half of the sugarcane planted area during all the period, followed by Paraná and Minas Gerais states. Second, the two states in the Northeast, Alagoas and Pernambuco, are decreasing its participation. Looking at the change in cultivated area between 1996 and 2006, Goiás, Mato Grosso do Sul and Minas Gerais, in the cerrado biome, presented the biggest change increasing by 344.3%, 248.4% and 189.4%, respectively Given that ethanol plants must be close to sugarcane plantations is expected that most of the expansion will be in the cerrado area.

<Table 4>

3.7. Vehicle Technology

Part of the Proalcool program was to encourage the development of cars that could replace gasoline with alcohol. Their major success was the development of 100% alcohol vehicles. The key technologies were developed by scientists at the Brazilian Aerospace Institute. Fiat produced the first 100% alcohol vehicle in 1979. Most other firms started building them. Figure 8 shows the rise and fall of pure alcohol vehicles. Their fall was caused by a rapid decline in production of alcohol in the late 1980s when oil was cheap and sugar was expensive.

In the 1990s when prices became more favorable for ethanol production again, the sugar and ethanol industry started to push both the auto manufacturers and the state to encourage flexfuel cars that could run on any mixture of ethanol and gasoline. The Brazilian branch of Magneti Marelli, the auto parts makers owned by Fiat, invested $10 million over 3 years in late 1990s to develop flexfuel vehicle (Tromboni et al.,.2009). Several other parts companies also invested in developing similar technology and brought it to Brazil. Ford, Volkswagen and Fiat also did research in Brazil to develop flex vehicles. These investments started to pay off in 2003 with the sale and rapid adoption of flexfuel vehicles. Now, almost all major car companies sell flexfuel vehicles in Brazil and they are dominating the new car market.

<Figure 8>

BIOEN is currently working with the industry to encourage the private sector to invest in increasing the fuel efficiency of flexfuel vehicles. They feel that major multinationals have pressed ahead with fuel efficiency of gasoline engines but not of vehicles which burn a lot of ethanol.

4. Future Prospects

4.1 Previous studies

There are several studies that simulate scenarios for the future of biofuels in the world and its consequences for prices, production, land use and trade. We will review a few then and focus and report their results for Brazilian sugarcane based ethanol production in order to assess the possibilities for sugarcane and ethanol industry in Brazil

Fernandez-Cornejo *et al*. (2008) use a general equilibrium model, under a set of economic policy, and two technological scenarios, to examine the medium term (2015) change in global welfare due to ethanol production.

They also estimate the changes in yield and ethanol production based on corn and sugarcane. The basic scenario, which is the moderate increase in productivity scenario, assumes that U.S. producers will produce around 15 billion gallons per year of corn based ethanol to meet the Revised Renewable Fuels Standard. Brazilian producers will produce to meet the national energy plan published by the Brazilian government. The second scenario assumes additional productivity gains for both Brazil and U.S.

Looking at the basic scenario prices and production results, they found that the 120% increase in sugarcane based ethanol would lead to a 53% increase in sugarcane production, sugarcane would increase by 24%, sugarcane land use increased by 52%, while sugarcane based ethanol prices decreased by 20% . "High" productivity had virtually no impact on land use or prices in this model. The high productivity scenario, where Brazilian additional productivity comes from an assumed 10% increase in productivity gains, the 120% increase in sugarcane based ethanol led to a 55% increase in sugarcane production, sugar or sugarcane prices increased by 24%, sugarcane land use increased by 51% while sugarcane based ethanol decreased by 20%.

Hertel *et al.* (2008) developed a special version of the Global Trade Analysis Project (GTAP) that was augmented by including the possibility of substitution between biofuels and petroleum products and by including the land use module that disaggregates land use in 18 Agro-Ecological Zones (AEZ). Through these 18 AEZ is possible to capture the potential for real competition between alternative land uses because they share common climate, precipitation and moisture conditions.

They use a historical period from 2001 to 2006 to validate their model and then they analyze the impacts of the biofuels boom on commodity markets for the 2006-2015 period. There are three scenarios, one that analyzes only the impact of U.S. biofuels program (15 billion gallons of ethanol by 2015), a second that analyzes only the impact of EU biofuels (6.25% renewable fuel use by 2015) program and a third that includes both policies. Results for Brazil are a 9.3% increase in sugarcane production due to U.S. policies and a 20.5% increase in oilseeds output due to EU policies. When looking at land use changes, they found that the increase in crops for biofuels production come from pastureland and commercial forest lands. They estimate an 11% decline in pastureland in Brazil, while they estimate that the EU, Canada, and Africa will have large percentage declines in commercial forestry.

Elobeid and Tokgoz (2008) use an international ethanol multimarket world model to examine the impacts of U.S.

tariff and tax credit removal on U.S. and Brazil. Two scenarios are analyzed, the first one considers only the tariff removal and the second considers both tariff and tax credit removal. The impact on Brazil in the first scenario is a 9.1% increase in production and a 64% increase in exports. Higher ethanol prices increase the use of sugarcane to produce ethanol by 4.9% and decrease the share of Brazilian sugarcane used to produce sugar. As a result, there is a 1.8% increase on sugar world prices.

When both tariffs and tax credits are removed, U.S. domestic prices increase by 16.5%, which is smaller than in the first scenario. U.S. imports increase by 137%. In this scenario, results for Brazil are also smaller, ethanol production increases by 6.3%, exports by 44% and the share of sugarcane in ethanol production increases by 3.4%.

The OECD-FAO agricultural outlook 2007-2018 report included projections for supply, demand, trade and prices of ethanol and biodiesel. The agricultural outlook is based on the Aglink partial equilibrium model. They assumed high oil prices and continued public support for biofuel in the U.S. and Europe as the main drivers of biofuels production. In their projections, ethanol production reaches 125 billion litters in 2017, which is twice the quantity produced in 2007. World ethanol prices should be around US$ 52-53 per hectoliter and trade should be almost 10 billion liters by

2017. Most of the ethanol trade will happen from Brazil to U.S. and EU. For biodiesel, they expect 24 billion liters production by 2017, and biodiesel prices in the range of USD 104-106 per hectoliter. International biodiesel trade will occur mainly from Indonesia and Malaysia to EU countries.

Fabiosa et al. (2010) use the FAPRI multimarket, multi-commodity international model to assess the effects of biofuels production on land allocations. They consider two scenarios, in the first one there is a 10% increase in U.S. ethanol demand, while in the second scenario there is a 5% increase ethanol demand in Brazil, China, the EU and India. In the first scenario projects that the increase in U.S. corn prices induce significant land allocations changes. The price effects influence the world prices and land allocation in Argentina and Brazil. If the U.S. removed ethanol import tariffs, Brazilian producers would increase their ethanol production to meet U.S. demand.

In the second scenario, the effect of ethanol expansion is felt mainly in Brazil through impact on sugarcane and sugar. Brazilian sugarcane area increases substantially and sugar production falls because sugar production competes with ethanol. They conclude that global effects of biofuels expansion on land are smaller than the increases in local demand and on the local ethanol industries. The U.S. ethanol expansion causes a large land reallocation in the U.S. between soybean and corn, while in Latin America there was a grain oil seed reallocation. Authors were surprised by the small global land effect of the Brazilian ethanol expansion.

In almost all of these studies, Brazil is the passive residual producer of ethanol, sugar, and soybeans. Only one of these studies (Fernandez-Cornejo) allows for any impact of technical change in Brazilian (or US) agriculture and in that case the assumed productivity has virtually no impact. The rest assume that crop and ethanol production technology will remain constant or grow according to past trends . All of the models except Fernandez-Cornejo, which sets production levels from the goals of the Brazilian government, let US and European policy determine Brazilian production. None of the studies attempt to model the impact of Brazilian policies on Brazilian ethanol and agriculture or on world prices.

4.1 Our Approach

In this paper we assume that the Brazilian ethanol industry production is determined by the biofuel policies of the U.S. and Europe as they work through international markets. We look at the effects of different technologies scenarios on Brazilian ethanol production and sugar, prices of ethanol and sugar, and land use. In another set of scenarios we look at the impact of possible land use policies and government policies and taxes on gasoline and ethanol prices.

The model used for the simulations is a modified version of GTAP-6, which is extended to allow energy capital substitution relationship as in the GTAP-E (energy) model by Burniaux and Truong (2002). In addition, the model accounts for the substitution between biofuels and fossil fuels. To introduce this substitution a nested CES function between biofuels (bioethanol and biodiesel) and petroleum products is incorporated into the structure of GTAP-E, an approach also used by Birur et al. (2007) and Hertel et al. (2008).

The GTAP 6 model contains 57 sectors, among them 20 represent agricultural and processed food sector. However, some of the sectors are aggregated, for example, coarse grains and oilseeds, and in order to get corn from coarse grains and soybeans from oilseeds we use the program Splitcom developed by Horridge (2005) and trade data from United Nations Commodity Trade Statistics Database (UNCOMTRADE). Besides, we created four new industrial sectors for the production of activities associated with biofuels, which are: sugar ethanol, maize ethanol, soybean diesel and rapeseed diesel.

The model also considers the effects of the production of byproducts such as dried distilled grains and soluble (DDGS) and biodiesel by-products (BDBP) that are generated when there is biofuel production. In order to do that it changed the output structure, from single to multi-output, and used a constant elasticity of transform (CET) function, which allows for optimization of output between biofuel and its byproducts. Because the byproducts are produced at an almost fixed share of their corresponding biofuel products, the elasticities in the CET function are given small values such as in Taheriopur et al. (2008). In addition, the model also considers the substitution between biofuel byproducts and other feed. To reflect this substitution, two levels of CES functions are included in the model. In the first level the substitutions among various feedstuffs in livestock production are allowed, in the second level, the substitution among DDGs and corn, BDP and processed feed are also introduced in the model. Another modification in the model is the land allocation. In the standard version of GTAP, different types of land are used as imperfect substitutes for each other; however, all uses have the same degree of substitutability. With this standard land structure is difficult to capture differences in substitutability that will arise. We use in our model a similar land structure as in Banse (2008), which allows for different degrees of substitutability among the cultivated land for different crops. Specifically in our model, the land use allocation structure is created by adding, to the standard GTAP model, a three-level CET nested structure that considers the different degrees of substitutability among different use types.

In conclusion, our model includes some features such as: a disaggregation of coarse grain and oilseed sectors in the GTAP database to extract corn and soybean, respectively; an introduction of four new industrial sectors; the possibility of substitution between biofuels and fossil fuels; a different approach for modeling land allocation; the introduction of a multi-output structure; and the substitution between biofuel byproducts and other feed inputs for livestock production. All those modifications permit a better assessment of the impacts of biofuels development on agriculture and the rest of the economy.

Scenarios

In order to build our simulations scenarios first we use historical data from the Brazilian statistics bureau and calculate the geometric growth rate of sugarcane yield between 1996 and 2006 census. During the ten years period the geometric growth rate was equivalent to 1.04% per year; from this number we construct a conservative scenario (alternative 1), which would imply half of the historical yield annual growth rate, 0.50%, and a more optimistic scenario (alternative 2), which would be double the historical rate and equivalent to a 2% yield annual growth rate. Besides considering feedstock productivity, we will also consider conversion technology improvements, that will be our third scenario. Based on the study by van den Wall Bake et al. (2009) we will consider a 10% improvement in conversion ratio (alternative 3). In alternative 4 scenario, we allow a 0.52% land expansion, where this number is a growth of rate calculation of land use according to FAO (Bruinsma, 2010) s. In alternative 5 scenario, we allow a gradual increase in substitution elasticity between gasoline and ethanol from 3 to 10 and in alternative 6 scenario we allow a double increase in petrol prices. Finally in alternative scenario 7 we combine the previous alternatives (5 and 6).

5. Conclusion

This study is an overview of Brazilian biofuels policies, technologies and research, and future simulations of biofuels demand that might affect the Brazilian biofuels industry. We examine the policies in place: the blend mandate and gasoline and ethanol pricing, taxes and credit incentives. This year there was a shortage of ethanol and prices increased. As a result the government is working on another national plan to give more incentives to increase investments and production. The government also approved a federal environmental law that established a gradual elimination of burning the sugarcane straw and approved a Decree that determined rules for the expansion of sugarcane land use (Sugarcane Agro-Ecological Zoning known as ZAE Cana). Sugarcane land use is monitored by the National Institute for Space Research (INPE) through a project that is called Canasat that maps sugarcane crop are using remote sensing satellite images.

In the case of biodiesel the government is also given incentives for mills that buy raw materials from family farmers, soybean is still the main raw material used for biodiesel production, but many oilseeds such as cotton, oil palm, castor beans, peanuts, sunflower among others have potential for the production of biodiesel but the challenge is to develop technologies to produce them. There is also an opportunity to produce biodiesel from perennial species in the Amazon, however, it is necessary to put social and environmental safeguards in place as well as instruments for government monitoring. Biodiesel technologies and production in Brazil are still far from the ethanol ones, it will require more time, incentives and regulations.

Both federal and state governments have made major investments in sugarcane breeding since the first half of the XX century. The main government institutions responsible for research are the Institute of Agronomy at Campinas, Instituto do Açúcar e do Alccol (later it was closed and scientists were distributed to seven federal universities in network called RIDESA), more recent EMBRAPA also started an agroenergy program. The private sector also has made many new investments. Besides CTC, funded by sugar and ethanol mills, Cana Viallis and Alellyx are working in sugarcane breeding and biotechnology. For the conversion of sugarcane into ethanol the private sector has been the main responsible for the development of new technologies, machines and logistics, Brazilian government supported this area mainly through credit. The results of over 30 years of research are an increase in efficiency and cost reduction of both feedstock and producing ethanol. Talking with scientists and researchers in the area they mention that is still room for improvement in the first generation biofuels. But even with this perception new government money has been allocated to second generation cellulose based biofuels made from bagasse. The private sector is also making new investments in biofuel production capacity and in improved conversion technology. More recently companies are also focusing on developing processes that will convert sucrose or biomass into “drop-in-biofuel” but recently discussions with scholars suggests that the technology will be ready to be implemented by about 2013 and it will start to make impacts on production around 2017.

Looking at future prospects through simulations from the literature, there is expectation of increase in Brazilian ethanol production, which depending on the scenario and timeline, varies from a 9.3% increase in production (Hertel et al, 2008) to a 53% increase (Fernandez-Cornejo et al., 2008). With the recent increase in oil prices, the Japanese nuclear accident, there is an expectation that biofuels will continue to develop as an alternative and there is an expectation in increase in production in the world and in Brazil.

For Brazil, ethanol and food crop production are opportunities for the industry and the agricultural sector without necessarily increasing land and/or destroying forest and biodiversity. Based on ethanol technologies that were developed and based on continuous research in the industry there is still room for increase in ethanol productivity. Even though there is land available for increasing crops and biofuels production in Brazil, there is also room for increase in certain crops and sugarcane productivity, this will varies depending on the Brazilian region and that exactly this possibility that we would like to explore. As a next step, we intend to investigate further and using a CGE model we will ask how Brazilian sugarcane yields historical average and twice this average, will impact agricultural prices (ethanol inclusive) and land-use allocation among crop alternatives in major countries in the world.

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Tables and Figures

Table 1 - IPI rates for cars - 2010

Cylinder	Ethanol or flex fuel	Ethanol or Flex Fuel
1000cc	3	7
Up to 2000cc	7.5	13
Over 2000cc	18	25

Source: Federal Decree 6.809/2009.

Table 2 - Brazilian Central Bank: Corporations Credit Operations Used as Reference for Interest rate

% per year

Period	**Hot money**	**Discount of trade bills**	**Discount of promissory Notes**	**Working capital**	**Guaranteed accounts**	**Purchase of goods**	**Vendor**
2009							
Dec	53,2	36,0	52,1	27,9	76,9	18,1	16,6
2010							
Jan	51,4	36,8	50,1	30,1	80,9	19,4	16,1
Feb	52,8	38,2	51,9	29,1	79,6	18,8	14,7
Mar	48,3	36,9	51,3	28,8	81,8	16,8	14,3
Apr	44,1	38,0	45,0	28,5	81,4	18,9	15,4
May	51,0	38,5	42,4	29,3	81,2	18,9	16,2
Jun	48,8	38,4	42,3	28,5	85,0	17,9	16,4
Jul	46,7	41,1	42,8	29,9	91,8	17,2	17,0
Aug	47,0	42,8	42,5	30,2	92,7	17,3	17,3
Sep	50,2	42,0	52,6	29,4	93,2	17,4	17,9
Oct	43,4	43,0	62,6	30,6	91,1	17,9	18,7
Nov	39,1	41,1	54,2	28,2	96,5	18,8	17,3
Dec*	46,1	39,1	53,6	27,3	95,7	17,0	16,5
2011							
Jan*	42,2	42,0	52,3	29,3	101,4	17,2	18,7
Feb*	44,8	44,5	58,1	30,5	101,2	18,0	17,8

Source: Brazilian Central Bank.

Table 3 - Reduction of federal taxes by region

	North, Northeast (castor and palm oil)	Center-West, South and Southeast	PRONAF farmers of all regions	PRONAF farmers of North, Northeast and Semi-arid (all raw materials)
Reduction of PIS/PASEP and COFINS	77.50%	73.57%	89.6%	100%

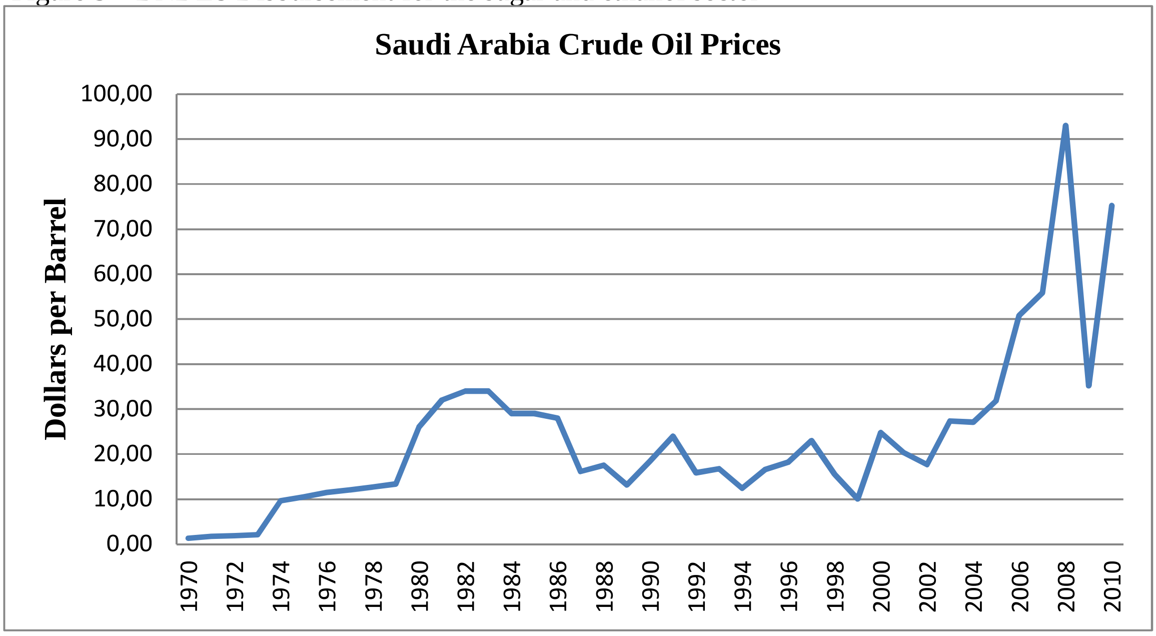
Source: Federal Decree 5297/94.

Table 4 - Brazilian states share of sugarcane cultivated area

States	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
São Paulo	51.61	50.11	50.79	51.35	50.92	51.11	51.12	52.40	52.40	53.05	54.70	54.90	55.31	55.82
Minas Gerais	5.12	5.72	5.53	5.63	6.00	5.88	5.34	5.64	5.94	6.00	6.75	7.01	7.43	8.17
Paraná	5.90	6.15	6.15	6.80	6.70	6.73	6.89	6.95	7.09	6.96	6.77	7.60	7.24	6.80
Goiás	2.44	2.36	2.85	2.98	2.85	2.59	3.91	3.12	3.13	3.44	3.72	3.92	5.07	5.99
Alagoas	8.95	9.26	9.15	9.09	9.47	9.11	8.41	7.73	7.51	7.00	6.29	5.80	5.29	4.96
Pernambuco	9.71	9.72	8.77	7.18	7.37	7.88	7.53	6.68	6.45	6.33	5.27	5.03	4.91	4.02
Mato Grosso do Sul	1.70	1.68	1.72	1.89	2.03	1.98	2.15	2.24	2.32	2.35	2.39	2.70	3.08	3.27
Mato Grosso	2.45	2.74	2.70	2.97	2.77	3.32	3.39	3.66	3.67	3.54	3.16	3.09	2.67	2.76

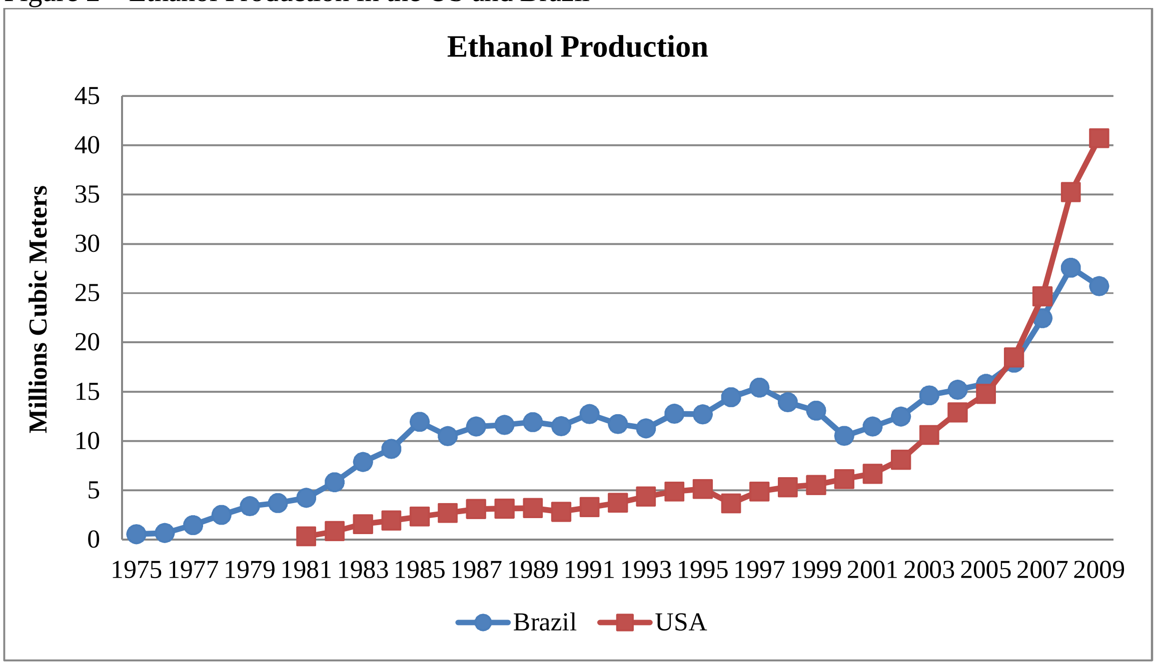
Source: PAM/IBGE.

Figure 3 – BNDES Disbursement for the sugar and ethanol sector



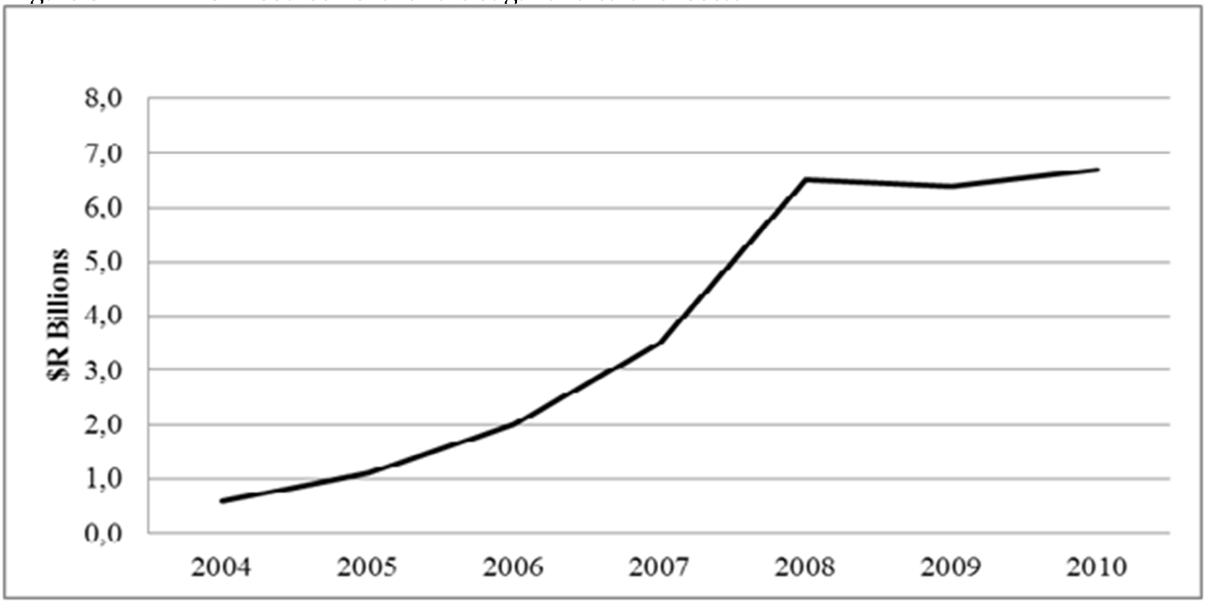
Source: The U.S. Energy Information Administration (EIA).

Figure 2 – Ethanol Production in the US and Brazil



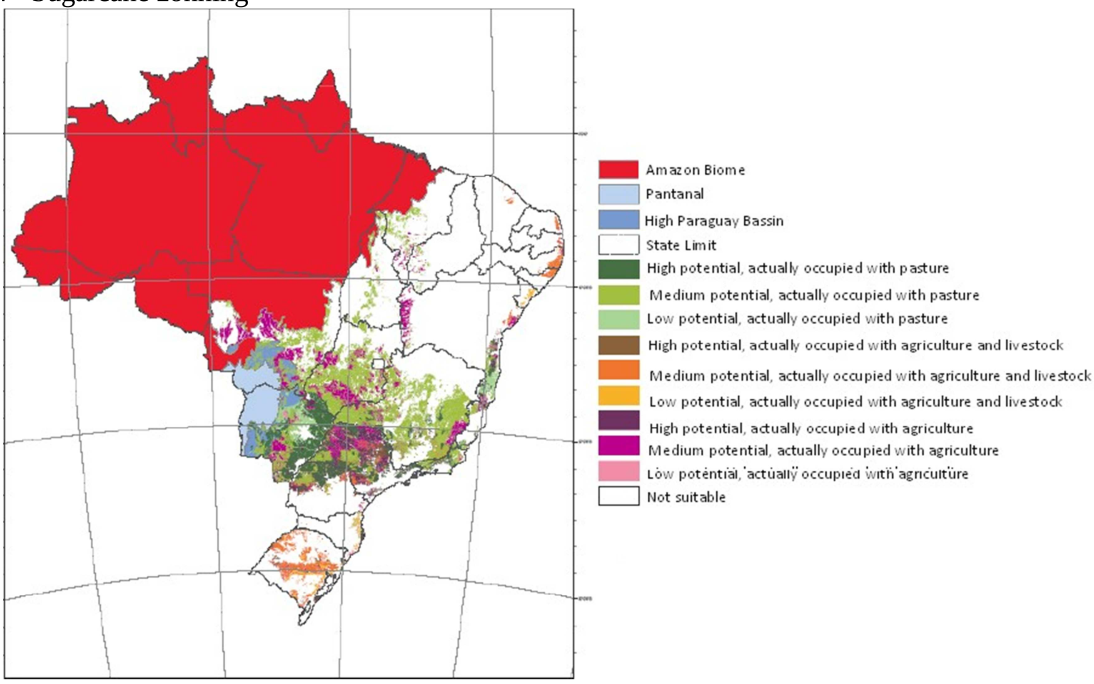
Source: Ministry of Agriculture, Livestock and Food Supply (MAPA) and the U.S. Energy Information Administration (EIA – Table 10.3).

Figure 3 – BNDES Disbursement for the sugar and ethanol sector



Source: BNDES

Figure 4 - Sugarcane zonning



Source: CANASAT.

Figure 5 – Contribution of feedstock costs to total ethanol production costs

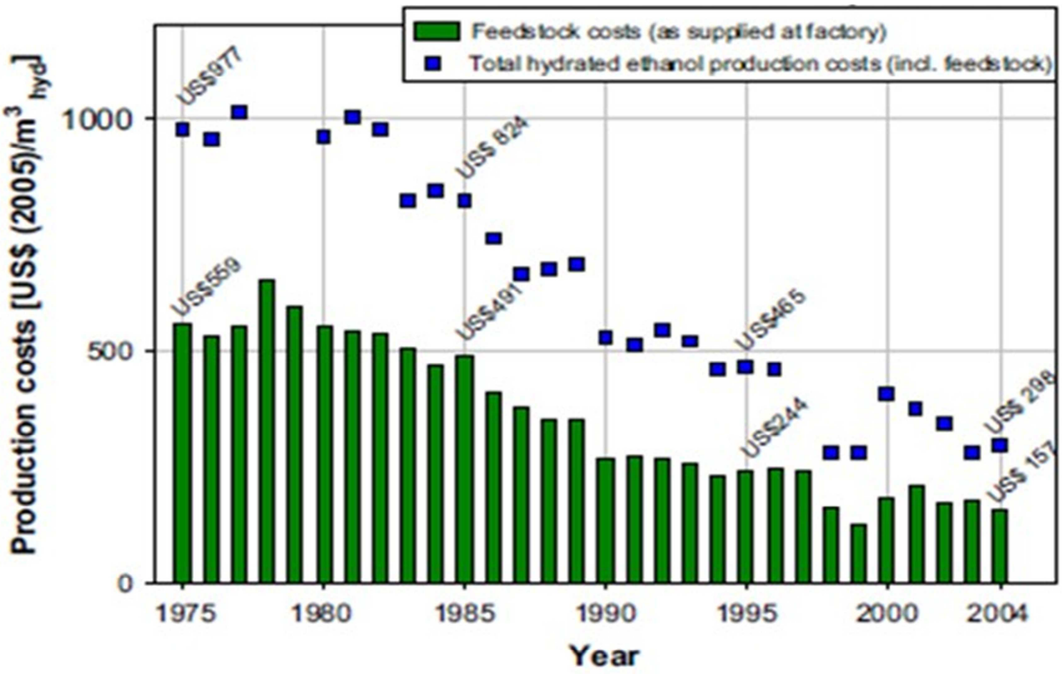
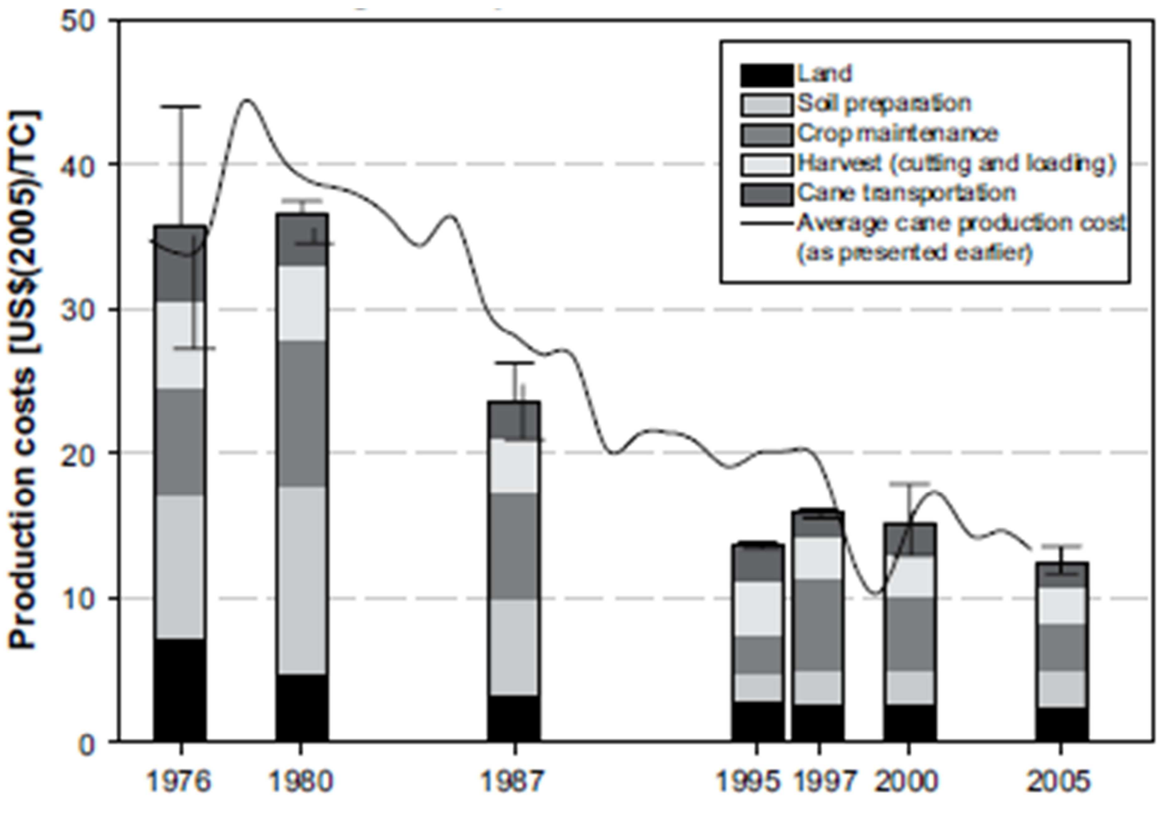
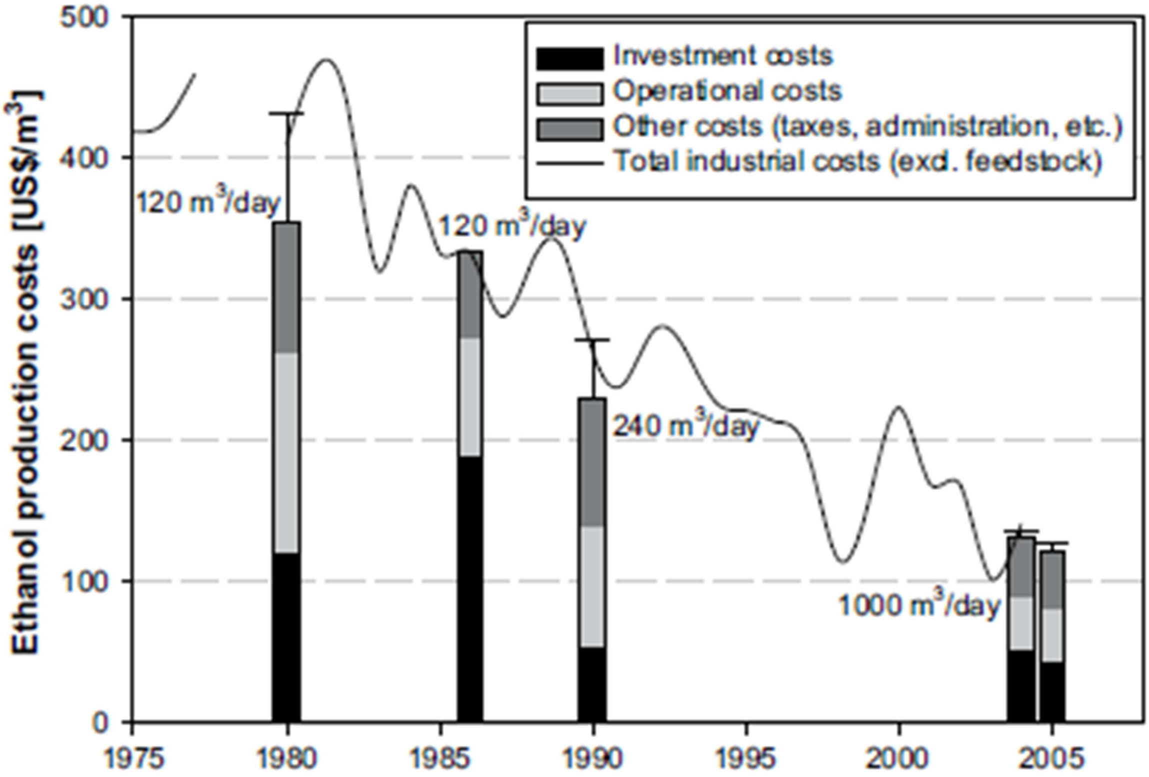


Figure 6 – Trends in the costs of sugarcane production



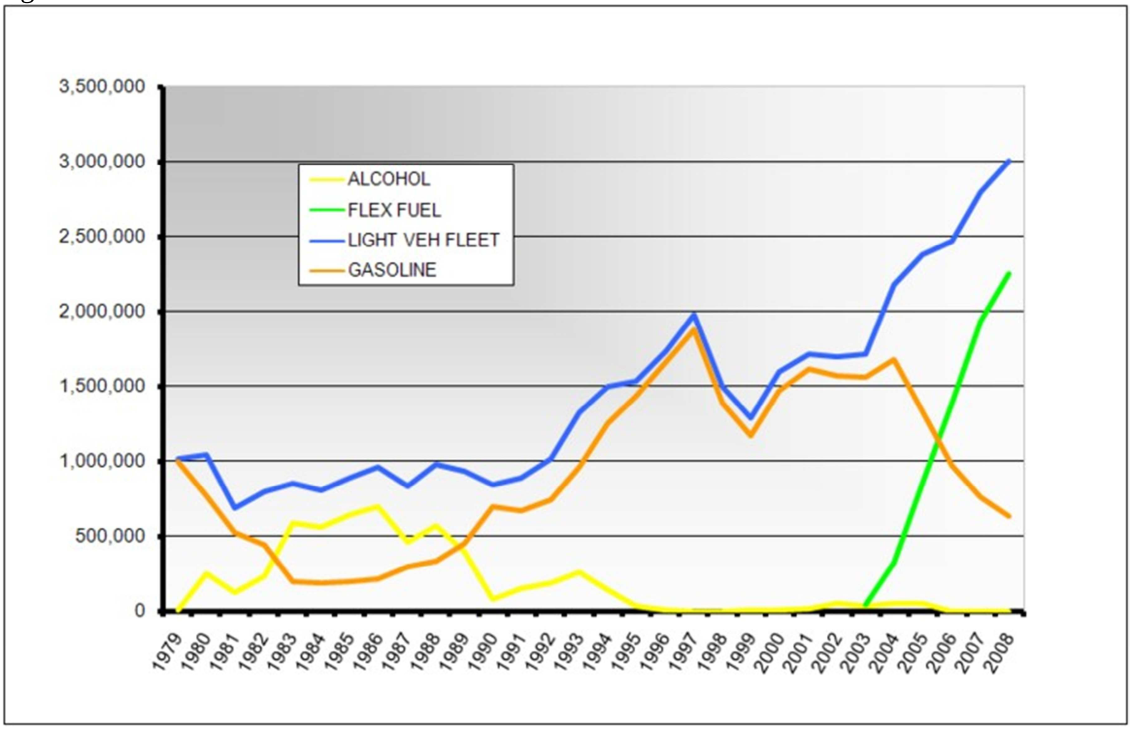
Source: van den Wall Bake et al. (2009)

Figure 7 – Trends in the cost of ethanol production



Source: van den Wall Bake et al. (2009)

Figure 8 - Sales of ethanol and flex fuel vehicles



Source: ANFAVEA.