The Evolution and Replicability of Biofuels in Brazil: Model or Exception?

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1. Introduction

Brazil's success in the production of alcohol fuel is strongly related to the action of the state as a designer of public policies. Historically, the Brazilian government has directly influenced the strategic decisions of the sector. The setting up of a regulatory framework (which has evolved though time), the concession of credit, the establishment of research institutions and the incentives for the emergence of a domestic and international demand for alcohol fuel are some of the main factors that indicate that the government has been a driving force in the establishment of Brazil's biofuel model. On the other hand, the existence of a consolidated and nimble sugar-cane private sector industry, that was willing to face the ensuing demands and challenges imposed by the government, - such as the creation of a new alcohol fuel market in the 1980's - is another major feature of the Brazilian ethanol model.

Despite the success of the Brazilian case, the replicability potential for sugarcane based biofuels in other countries is still to be further explored. Latin American and Caribbean nations, for instance, in addition to African countries with appropriate soil and climate conditions, could easily absorb the existent technology for ethanol production. The establishment of ethanol as a *commodity,* and the increase in international demand could boost the interest from governments for replicating the Brazilian model. In this paper we will argue, however, that the state-market partnership is a core condition for the sustainability of the model. In many cases, furthermore, the participation of foreign investment is desirable and necessary.

2. The Brazilian model

The Brazilian model of ethanol production has some important characteristics. First of all, it is important to note that the production of ethanol in Brazil is strongly linked to the historical existence of a sugar sector since the days of Portuguese rule. A second important point is the fact that the Brazilian model of ethanol production was erected based on the state – market duality.

The technological consolidation of Brazil's ethanol program was strongly supported by the state, either through specific programs for the sector, or through technical and scientific support by public research institutes. The state sought to offer the necessary conditions for overcoming the sector's technological and even financial bottlenecks. At the same time, it sought to bring the sugar-alcohol production closer to the most dynamic center of Brazil's economy (Furtado and Scandiffo, 2007), in an attempt to increase the economic efficiency of the sector. This strong state presence as a fosterer in the development of public policies had an inducing and stabilizing character, signalizing to the market that the option of such technological path would be government supported.

At the same time, the state also opted for backing the automotive industry in the development and production of an alcohol-fueled fleet. Thus, the government supported both the supply production and the demand for this product, as it encouraged and partially financed the automotive production.

It is important to highlight that the two central challenges for the ethanol program – the technological and the market bottlenecks – were overcome along the 1980s and 1990s. From the technological standpoint, there were various gains with the incremental innovations in the production process, enabling increasing scale gains in the ethanol production, along with (exogenous) technological innovations in the motorization of vehicles. From the marketing standpoint, the sequence of oil crises, through which a stable price around US$60 per barrel can be observed, made way for the market gains of ethanol. From a mid-term perspective, the Kyoto Protocol may further leverage the sector of renewable fuels through the various mechanisms that it considers.

Therefore, we may affirm that the Brazilian model, based on the state – market duality – which is also present in other sectors of the national economy (e.g. aeronautics, petroleum), was a successful case, whose results were strengthened by a dynamics of pressures related to environmental concerns.

3. Brazil's ethanol program origins and evolution

The Brazilian ethanol production case is very unique and has some characteristics that must be highlighted. Initially, we find the country's historical identity as sugar cane producer. But it is from the government's commitment with mid- and long term expectations in the 1970s that a basic element for the full implementation of the ethanol program in the country can be observed. The production of sugar cane – the main feedstock of the Brazilian alcohol – dates back to the colonial days. One may affirm that sugar cane was the first trade product of colonial Brazil, which became its leading world producer in the 16th and 17th centuries.

Although the sugar cane production entered a decline during the 18th century, it is possible to consider that this decline was relative. After all, sugar cane was still an important economic activity, especially in Brazil's Northeastern region. From the 16th to the 19th century as a whole, the external market was the main destination of the Brazilian sugar cane. Such scene only changed in the early 20th century.

Already in the 1930s, the Brazilian government sought to apply countercyclical policies for the sector, through purchases and by creating regulatory stockpiles through the newly founded Institute of Sugar and Alcohol, IAA (Furtado and Scandiffo, 2007).

Gradually, the internal market became the main destination for the national sugar cane. This change of destination axis entailed a geographical shift, and production became more intense in the Brazilian Southeast, especially in the state of Sao Paulo.

Another important aspect of this period is related to the decision to begin adding alcohol to gasoline fuel. This factor was crucial for the consolidation of a strong sugar-based agro-industry in the state of Sao Paulo, the state with the most consolidated industrial park in Brazil.

The international market only returned to the scene in the 1960s. It was in this period that the Brazilian government, motivated with the resumption in exports, sought to modernize its agro-industrial park through plan Planalsucar, which was implemented during the 1970s (Furtado and Scandiffo, 2007).

It is at that stage that one finds an important economic turning point for the implementation of the policy of alcohol fuel as an option to gasoline. With the first oil crisis, the Brazilian government was forced to seek alternatives to the use of gasoline as the main fuel for the automotive fleet. In was in such context that the National Alcohol Program – ProAlcool – came into existence in 1975. Its main goal was to implement a large-scale substitution of oil derivatives by alcohol (Hira and Oliveira, 2009). The program may be seen in three phases: i) 1975–1976, when 600 million liters of ethanol were produced; ii) 1979–1980, when the production reached 3.4 billion liters; and iii) 1986–1987, with a total production of 12.3 billion liters.

Some important factors consolidated the ProAlcool during its stage of transition, or ripening (that is, during the 1st and 2nd phases), in particular the 2nd oil crisis (Barzelay, 1986). At that moment, the Brazilian government adopted a guideline of reducing as much as possible its dependence on oil, which was necessarily a foreign commodity[1], in order to relieve its foreign accounts. Thus, we may affirm that the ProAlcool's main motivation on the part of the Brazilian government was the effort to oxygenate foreign accounts and overcome the severe macroeconomic crisis that was emerging on the horizon.

The consolidation of that crisis paved to way to the success of ProAlcool's 3rd phase, when the production reached the significant volume of 12.3 billion liters of alcohol. Meanwhile, the macroeconomic crisis had reached its peak, along with two-digit inflation levels and a chronic insufficiency of resources in the foreign accounts.

The Program's idyllic horizon started to change in the beginning of the 1990s, when one observes a moment of stability in the oil price, along with a strong pressure of external demand through the sugar market (van den Wall Bake, 2006). It was starting in this period of 1985–2002 that the Program underwent its most critical phase, including moments when it was necessary to import alcohol for an internal demand that became increasingly skeptical about the Program (Hira and Oliveira, 2009).

[1] The oil production in Brazil gained importance starting at the late 1980s and early 1990s, when Petrobras was able to overcome the technological barriers for offshore oil exploration.

However, starting in 2004, the Program experienced a “rebirth” with the junction of two important points: i) the beginning of a strong increase in the oil price; and ii) the launching of the ‘flex’ bi-fuel automobiles. The more significant of these two factors was in the flex cars, whose technology was developed in the United States starting at the late 1980s. The adoption of flex cars gave consumers the ability to choose the fuel to be used. Thus, consumers could minimize eventual price seasonalities in the market prices of alcohol and oil.

4. Institutions and regulatory framework

The trajectory of the ProAlcool program was supported by a number of research institutions which the government established with the objective of overcoming technical challenges for the adoption of ethanol in Brazil´s energy matrix. In conjunction to research and development efforts, the government designed a regulatory framework that was key in generating gains in competitiveness in the ethanol production chain.

4.1 – Research & Development efforts

The creation of a public Sectorial Innovation System – SSI (Malerba and Mani, 2009) to strengthen R&D activities allowed the sugar-alcohol sector to overcome a strong bottleneck towards the technological development of alcohol as an energy matrix. In this sense, we find the strong involvement of the state in order to effectuate the SSI through public research institutes and state companies, through the federal and state-based university-infrastructure, and through credit lines for R&D activities.

Historically, the Brazilian state has acted to support R&D activities in the sugar-alcohol sector. In spite of finding a few efforts in the academic universe, with a highlight for the Luiz de Queiroz Agriculture College – ESALQ/USP, the first public action organized to foster R&D for the sector started with the creation of the Institute of Sugar and Alcohol, IAA, in the 1930s. Later, the Agronomic Institute, IAC, began to act with an effort to improve the sugar cane production. In the 1990s, with the closing of the IAA, its research structure was transferred to the Sao Carlos Federal University – UFSCAR.

In the 1970s, we find the creation of the Coopersucar Research Center – CTC, an action by the leading cooperative of the sugar-alcohol sector (Fronzaglia and Martins, 2006). Although this action originated as a private initiative, the public sector strongly acted in the concession of credit for its structuring.

The incorporation of alcohol to the Brazilian energy matrix included other actors in the SSI setting. Here, the highlight was the Technical Aerospace Center – CTA, through the Air Force Technological Institute – ITA. The CTA is an important aerospace research center and its governance is subordinated to the Ministry of Defense and to the Air Force Command (Hira and Oliveira, 2007).

Another important actor in this construction process of the SSI is the Institute of Technological Research – IPT, which is also located in the state of Sao Paulo. To the IPT were added the Advanced Center for Technological Research in the Sugar Cane

Agribusiness – CAPTAC, the Biological Institute – IB, and the Institute of Agricultural Economics – IEA. Additional highlights include Petrobras through its Research and Development Center – CENPES; the Brazilian Company for Agriculture and Livestock Research – Embrapa; and the recently established Bioethanol Science and Technology Center, linked to the Ministry of Science and Technology.

One should also point to the structuring of an inter-university network for the development of the sugar-alcohol sector, including eight federal universities (UFPR, UFSCAR, UFV, UFRRJ, UFSE, UFAL, UFRPE and UFG), and to the Sao Paulo state network of universities (USP, Unicamp and Unesp). Although the Sao Paulo network is a state-based effort, many of its financing sources for research are federal, especially through the Ministry of Science and Technology – MCT.

4.2 – Legal framework

Starting in 1990, the state has adopted various laws, rules and norms that sought to enable competitiveness gains, and which became crucial elements in the consolidation of a successful path for the sugar-alcohol sector. From the 90s on, the sugar-alcohol sector started to count with a very favorable set of institutions. As a result, we find important competitiveness gains, especially in the state of Sao Paulo.

Among these factors, the following should be highlighted:

- The sector's deregulation at the late 90s motivated an increase in the productive, technological and managerial efficiency at the mills;

- The financing Program for the adoption of information technologies (MCT Ordinance 200/1994) motivated the purchase and development of integration systems for managerial processes.

- Federal Act 8,989/95 reduced the IPI tax (and, consequently, the IPVA tax) for alcohol-fueled cars, motivating the consumption of alcohol fuel;

- Federal Decree 2,607/1998 set between 20 and 25% as the percentage of alcohol to be mixed to gasoline. This norm ensures an internal market reserve for alcohol;

- Brazil's National Development Bank's (BNDES)Program MODERFROTA (1999) fostered technological modernization and renewal in the agro-industry;

- Act 10,547/2000 (Sao Paulo) motivated the mechanization and rationalization of cutting and logistical operations in the sugar-alcohol production chain;

- Constitutional Amendment 33 (Dec. 11, 2001) defined the tax regime on fuels. This mechanism allowed the adoption of cross subsidies; imports and trading of oil products were overtaxed in order to subsidize alcohol.

- Act 10,453/2002 defined instruments of economic policy through which the state may interfere in the production and trade of alcohol, especially in the North and Northeast regions.

5. Market friendly policies

The market proximity factor had a crucial role in the success of the Brazilian alcohol policy. In this sense, we find that, along with the external pressures – due to the oil crises –, a domestic market was forged with the creation of an alcohol-fueled car fleet. Further on, an additional element was added to the scene with the emergence of a new carbon credit market. At all ends, it is interesting to note the convergence among the interests of the state and the interests of the market.

5.1 – The traditional market – automotive industry

Although the effort to think about alcohol as an energy matrix for the automotive fleet dates back to the first half of the 20th century, such process only began in a coordinated way in the 1970s with the ProAlcool program.

As Table 1 describes, the commerce of alcohol-fueled cars started in 1979 with 2,271 units. This number increased dramatically already in 1980, when 226,352 units were sold (an increase of 9,867%). Up from 1980, the business of alcohol-fueled cars increased and reached 619,290 units in 1986, accounting for 92% of the year's new fleet. The main reason behind this increase was the strong subsidy to alcohol fuel, which became an attractive option for consumers. And a new record was reached in 1987, when the share of alcohol-fueled cars in the total fleet sold in Brazil for the year reached an impressive 94%.

Table 1 – Automobile units sold in Brazil 1978 - 2007

YEAR	AUTOMOBILES		
	GASOLINE	ALCOHOL	FLEX FUEL
1978	797,942	-	-
1979	826,462	2,271	-
1980	566,676	226,352	-
1981	318,929	128,679	-
1982	344,468	211,761	-
1983	70,098	538,401	-
1984	28,670	503,565	-
1985	23,892	578,177	-
1986	53,094	619,290	-
1987	23,084	387,176	-
1988	64,734	492,010	-
1989	220,984	345,598	-
1990	462,585	70,250	-
1991	468,462	129,139	-
1992	431,635	164,840	-
1993	675,403	227,289	-
1994	1,007,462	119,203	-
1995	1,374,265	32,808	-
1996	1,399,212	6,333	-
1997	1,568,803	924	-

1998	1,210,904	981	-
1999	1,001,996	9,851	-
2000	1,167,164	9,610	-
2001	1,280,117	14,979	-
2002	1,181,780	47,366	-
2003	1,046,474	33,034	39,095
2004	967,235	49,801	278,764
2005	609,903	30,904	728,375
2006	260,824	1,650	1,293,746
2007	186,554	88	1,780,876

Source: ANFAVEA

The scene maintained itself favorably until 1989, when the share of new alcohol-fueled cars reduced to 61%. In 1990, it fell to 13%. Such fall in the commerce of alcohol-fueled cars continued and, in 1998, their share in the number of newly sold cars bottomed at 0.08%.

This fall trajectory can be explained with reference to some factors. Firstly, the period experienced a strong increase in the foreign price of sugar cane, which occasioned a destination shift in the alcohol business from the domestic to the foreign market, and this phenomenon pressured the price of alcohol fuel, which was already subsidized. A further element was the relative stability in the oil price between 1989 and 1998. These factors ended up undermining the trust of consumers in the ProAlcool program (Hira and Oliveira, 2009).

The great resumption of alcohol fuel took place in 2003-2004 with the launching of the bi-fuel, or flex-fuel cars. In 2003, the share of the flex fleet reached 3.4% of the total selling. By 2007, this share had leaped to 90.5%. The main factors that contributed to this process were the instability in the oil price, added to its high cost. Another important point is the technological factor. The flex-fuel technology overcame some technical problems related to the alcohol engines of the previous generation, and also gave the consumers the ability to opt for their fuel. Finally, it was up from the decade’s early years that the discussions on the environmental impacts and the automobile fleet increased their public exposure, prompting the consumers to consider the environmental advantages of alcohol-fueled cars.

A comparison of advantages and disadvantages between gasoline and ethanol allows the following considerations:

* Advantages of petroleum (Hira and Oliveira, 2009):

- It is less corrosive on engines, even though non-corrosive materials that resist alcohol have been more recently designed;
- It yields more energy per unit of volume, thus allowing for smaller fuel tanks;
- It has a lower ignition temperature, which enables easier starts under cold weather;
- There are many important petroleum by-products, including plastics and fertilizers.

* Disadvantages of petroleum vis-à-vis alcohol-based fuel:

- Petroleum has a lower octane rating, and a higher toxicity;
- It produces more dangerous and threatening pollutants;
- It is more likely to explode and burn accidentally;
- It is more threatening to the environment if spilled or leaked;
- It leaves a residue gum on surfaces where it is stored, and the fuel leaves carbon deposits in combustion chambers;
- It requires extensive pipeline networks, and incredibly risky, expensive exploration and development. Alcohol can be produced, by contrast, by small economies of scale.

5.2 – Sugarcane production

Brazil is the world's leading producer of ethanol from sugarcane. Its regional highlight is found in the Central-South region, which accounts for 87% of the national production. It is important to underline that, from sugar cane, both sugar and alcohol can be obtained. In a general way, it is found that some 50% of the overall production goes for each product. In the 1970s, the sugar share in the sugar cane production was of 90%, whereas in the 1980s this share reverted and 80% of the sugar cane production was destined to become alcohol. This turn result is explained by the ProAlcool program.

Table 2 below describes the sugarcane production from 1990 to 2008. One finds a concentration in the production of the Central-South region, and stagnation in the North-Northeast region.

Table 2 – Sugarcane production in Brazil (in thousands of tons)

Crop Year	Central-South	North-Northeast	Brazil
90-91	170,194	52,234	222,428
91-92	179,031	50,191	229,222
92-93	176,218	47,164	223,382
93-94	183,914	34,421	218,335
94-95	196,083	44,629	240,712
95-96	204,414	17,413	221,827
96-97	231,604	56,205	287,809
97-98	248,775	54,282	303,057
98-09	269,781	45,141	314,922
09-00	263,949	43,016	306,965
00-01	207,099	50,523	257,622
01-02	244,218	48,832	293,050

02-03	270,406	50,243	320,650
03-04	299,406	60,194	359,315
04-05	328,697	57,392	386,090
05-06	337,714	49,727	387,441
06-07	372,285	53,250	425,535
07-08	431,184	64,609	495,794

Source: Unica

A closer look reveals that the state of Sao Paulo concentrates 62% of the sugar cane production, followed by the states of Parana (6.5%), Minas Gerais (6%), Mato Grosso (4.8%), Goias (4.5%), Alagoas (3.4%) and Pernambuco (2%). The other states account for a total of 10.3% (Buainain and Batalha, 2007).

The Brazilian sugar cane production yields two main alcohol types: i) anhydrous alcohol, which is mixed with gasoline, and ii) hydrated alcohol, which is used for alcohol-fueled cars and flex cars. As Table 3 shows, the anhydrous alcohol output increased 748% between 1990 and 2008, due to the federal act that demanded the mixture of this product with gasoline in a proportion of 20 to 25%.

Table 3: Brazilian production of anhydrous alcohol and hydrated alcohol (m3)

Crop Year	Anhydrous	Hydrated	Total
90-91	1,286,568	10,228,583	11,515,151
91-92	1,986,794	10,735,439	12,722,233
92-93	2,216,385	9,513,106	11,729,491
93-94	2,522,589	8,769,596	11,292,185
94-95	2,873,470	9,892,440	12,765,910
95-96	3,057,557	9,659,202	12,716,759
96-97	4,629,340	9,801,109	14,430,449
97-98	5,699,719	9,722,534	15,422,253
98-99	5,679,998	8,246,823	13,926,821
99-00	6,140,769	6,936,996	13,077,765
00-01	5,584,730	4,932,805	10,517,535
01-02	6,479,187	4,988,608	11,467,795
02-03	7,009,063	5,473,363	12,485,426
03-04	8,767,898	5,872,025	14,639,923
04-05	8,172,488	7,035,421	15,207,909

05-06	7,663,245	8,144,939	15,808,184
06-07	8,078,306	9,861,122	17,939,428
07-08	8,464,520	13,981,459	22,445,979
08-09	9,623,020	17,959,717	27,582,737

Source: Unica

An interesting characteristic of the sugar cane business is the reduction in the production costs of alcohol and sugar, due to the fact that the energy used in the process is obtained from its own residues (bagasse, vinhoto, straw), in a system named cogeneration. This feature collaborates significantly in the productivity gains of sugar cane alcohol as an energy matrix.

5.3 – Key aspects of the alcohol market

As was previously mentioned, an important characteristic of the sugar-alcohol sector is the historical fact that Brazil has had a friendly market for the alcohol demand. Presently, there are other important aspects that contribute to make this environment even friendlier. The Kyoto Protocol sets a 5.2% reduction of greenhouse emissions between 2008 and 2012. Evidently, such reduction is an important window of opportunity for the alcohol production not only for Brazil but for other leading producers.

One challenge for the sector is trying to estimate the increase in the international demand, and how such increase may imply in a pressure on the domestic market. On the other hand, an overestimation of the international market increase may strongly discourage the sugar-alcohol sector.

It is in this space that the Brazilian public powers may seek to act as regulating actors in the demand and supply of ethanol, at least for the domestic market, by means of technological improvement initiatives such as PROINFA – Program of Incentive to Alternative Sources of Electric Energy –, or through Petrobras.

6. From environmental concerns to food security: some current issues

The production of alcohol became even more relevant due to the environmental agenda that has been discussed since the beginning of this century. In this sense, the factors that become more important are the ones related to energy balances and to the increase in the crop areas (with a highlight for the Amazon region). Once again, it is in this space that the need emerges for the state presence as a regulating actor able to set limits and practices for the sector.

Initially, during the production stage of alcohol, the important process is the use of sugar cane residues for energy obtainment, named cogeneration process. In a second moment, one must focus the question of comparing the production of alcohol from sugar cane with other crops. According to a recent Embrapa work, one hectare of sugar cane produces 3,244kg of greenhouse gases, in terms of CO2-equivalence, whereas soy and corn crops produce an average 1,160kg, and pastures produce 2,840kg. Nonetheless, one hectare of sugar cane substitutes 4,500 liters of gasoline, whose emissions produce 16.4 tons of CO2 a year into the atmosphere. The result is that each hectare of sugar cane transformed into alcohol and used as a substitute for gasoline allows a reduction of more than 12 tons in the yearly emissions of CO2 (FAPESP, 2009).

The increasing mechanization of the sugar cane harvest in substitution to the habit of burning the land – which is expected to clean the soil, but emits greenhouse gases such as CO2 and methane (CH4) into the atmosphere - favored the energetic balance of the ethanol production. Nowadays, mechanization has reached 60% of the farming land in the state of Sao Paulo and, by force of law, it will reach all sugar cane farms until 2022 (FAPESP, 2009).

6.1 – The increase in production

The sugarcane sector use of farm land in Brazil has been stable in the last decades. Most of the crops and ethanol mills continue to be concentrated in Brazil´s Southeast region. Contrary to environmentalist fears, figures have shown that sugarcane production is not threatening the Amazon region. The North region of the country does not have the most appropriate soil and climate conditions for sugarcane production, therefore acting as a natural hurdle for the expansion of the production to these areas.

This fact can be illustrated with the analysis of figures from the Brazilian Institute for Geography and Statistics (IBGE) for the year of 2007. From Brazil´s total land área of 851 million of hectars, rural property accounts for 355 hectars (42 percent of the territory), while farm áreas account for 76.7 million (9 percent of the total) and sugarcane farms account for only 3.6 million hectars (0.5 percent of the Brazilian territory).

Taking into account the concentration of the production in Southeast Brazil, it is important to outline that it was induced by the state, which established incentive mechanisms for production in this region. The productive sector, on the other hand, seized this window of opportunity by obtaining significative productive gains. (Furtado e Scandiffio, 2007).

This process has increased in the past decade. As Table 4 shows, the number of processing mills increased significantly in the Southeast region, whereas it has either stagnated or slightly reduced in the other regions. In the North region, the number of processing mills is the same as in the period from 1991 to 2005.

Table 4 – Number of sugar and alcohol mills

Safra	Nordeste	Norte	Sudeste	Centro-Oeste	Sul	Total
1991-1992	**116**	**3**	**190**	**34**	**30**	**373**
1999-2000	80	3	169	29	29	310
2003-2004	**105**	**3**	**217**	**35**	**33**	**393**
2004-2005	74	3	214	36	28	355

Fontes: IEL/NC e Sebrae (2005), Udop e Jornal Cana.

Table 5 shows that the alcohol production scene followed this trend. The state of Sao Paulo is the highlight with a 62.5% share. In the North region, where the Amazon is located, no state is listed among the 10 main producers. Even the Midwest region did not present a significant increase in alcohol production.

Table 5 – All-purpose alcohol output, 2005-2006, leading states

Estado	Produção (m^3)	Participação (%)
São Paulo	9.951.710	62,5
Paraná	1.042.646	6,5
Minas Gerais	966.122	6,0
Mato Grosso	770.585	4,8
Goiás	718.414	4,5
Alagoas	546.046	3,4
Pernambuco	328.059	2,0
Outros	1.612.300	10,3
Total	15.935.882	100,0

Fonte: Unica.

7. Replicability of the Brazilian Model: Possible and Necessary

The replicability of the Brazilian model in other countries would be justifiable for various reasons: (i) sugarcane ethanol is more economically competitive; (ii) it has a more efficient energy balance and emissions of green house gases are lower; (iii) the increase in world demand for ethanol and the establishment of a global biofuels market could offset domestic market limitations; (iv) technology is readily available and could be easily adapted; (v) it could be an economic feasible alternative for developing countries.

In comparative terms, sugarcane ethanol is more competitive than the bioethanol generated from other feedstocks (i.e. beat, wheat, cassava and corn). With smaller production costs and greater productivity, sugarcane ethanol is a more economic viable alternative than the other feedstocks (CGEE, 2004). Furthermore, sugarcane ethanol accounts for a more efficient energy balance, and reduction in green house gas emissions (GHG) are more significant than using other feedstocks. Even the theoretical estimates for GHG emissions with cellulosic ethanol are not as promising as reductions with sugarcane ethanol. This comparison can be better seen in table 6.

Table 6. Comparison of different feedstock for bioethanol production

Feedstock	Energy ratio	Avoided emissions
Sugarcane	9.3	89%
Corn	0.6 – 2.0	-30% a 38%
Wheat	0.97 – 1.11	19% a 47%
Beet	1.2 – 1.8	35% a 56%

Cassava	1.6 – 1.7	63%
Lignocellulosic residues*	8.3 – 8.4	66% a 73%

BNDES (2008)
* Theoretical estimate, process under development

Taking into account the consumer market potential for renewable fuels, the increase in global demand and the establishment of a world ethanol market could represent a window of opportunity for other potential sugarcane ethanol producers. Current projections estimate that the addition of 10 percent of ethanol in gasoline worldwide would represent the consumption of 136.5 billion litters per year. (BNDES 2008). In 2007, total world ethanol production was 55.7 billion litters. Therefore, the increase in consumption would be only sustained through the internationalization of the bioethanol production. Furthermore, with the establishment of a global ethanol market, small countries with inexpressive domestic consumption of ethanol could produce for attending the foreign demand.

In technological terms, the production process of sugar based ethanol (i.e. sugarcane and beet) is simple and requires less steps than required for the production of starch-bioethanol. Furthermore, mills producing sugar can be easily converted into ethanol producing and can in fact yield both products. Ethanol logistics and infra-structure requirements are similar to the ones required for fossil fuels. Currently, the main producers of sugarcane are: Brazil, Índia, China, Pakistan, Mexico, Thailand and Colômbia (FAO 2007). However, this production could be expanded to various tropical areas (i.e. Latin America, Caribbeean and Africa). In fact, for some countries like Guatemala, El Salvador and Costa Rica, this would be the resumption of production, since they had an experience with ethanol in the 1980s.

As we have demonstrated, ethanol production could be an interesting alternative for developing countries. However, there are some challenges for the replicability of the Brazilian model. First of all, the binome state-market needs to be present. It is very unlikely that ethanol will enter a fuel market without government support and the implementation of the necessary regulatory framework. At the same time, it is necessary the existance of a consolidated market to attract private investments for the sector. A second condition would be the transfer of technology for new entrants, which would be key for generating a competitive production. Finally, the establishment of mecanisms allowing for capital flow to the sector, even if based in foreign investments, to finance production in a large scale, generating feasible economic results.

8. Conclusions

The Brazilian model of alcohol fuel production has some specific characteristics that cannot be neglected. It is important to highlight that this is a very traditional sector of the Brazilian economic culture, which made way for the consolidation of some public institutions that contributed to its technological evolution.

However, the most interesting aspect of the Brazilian case is the relation between market and state in the trajectory of the sugar-alcohol sector. It is noteworthy that the market led the evolution in the sector, as external and internal demands motivated a dynamic sector able to attend both national and international needs. The state, on its turn, induced the market in regard to strategic aspects such as: i) technological options; ii) technological and productive infrastructure; and iii) stimuli for the creation of a specific alcohol-consumer market.

This juxtaposition or partnership between state and market made possible a fast development of the demands related to gains of competitiveness in the sugar-alcohol sector, to the point where it has become one of the most dynamic sectors of the Brazilian economy. Such institutional dynamism is probably the greatest achievement of the state in regard to the successful trajectory of the sector.

An important point for the replicability of the Brazilian model in other countries is related to the possibility of technological transfers that facilitate the successful setting of alcohol as an energy matrix. This aspect is crucial and it would be unlikely to imagine that new producers should follow the same technological path of the Brazilian model. In this sense, it is necessary to create mechanisms with a view to the ‘technological leap’ that may enable the competitive access of newcomers to this market. It should be stressed that the adoption of alcohol fuel in an international scale is only viable if production itself is internationalized.

At the same time, new producers must create a mechanism able to attract capital – even external capital – and secure the creation of a consistent sugar-alcohol sector. The replicability of the Brazilian model, based as it is on the relation between state and market, cannot be sustained if one of these two bases is inconsistent. Therefore, the condition for a possible replication is the existence of public policies that consider: i) attracting capital to the sector; ii) creating the institutions that back the producers; and iii) creating a mechanism that enables real gains of competitiveness. In spite of the existing challenges, the Brazilian model can be replicated, especially in developing countries in Central America and Africa that present favorable conditions for the production of sugarcane.

References

Barzelay, M., 1986, *The politicized market economy: alcohol in Brazil’s energy strategy*. Berkeley: University of California Press.

BNDES (Brazil’s National Development Bank Brazil), CGEE (Center for Strategic Studies and Management), ECLAC (UN Economic Commission for Latin America and the Caribbean) and FAO (UN Food and Agriculture Organization), 2008, *Sugarcane-based bioethanol: energy for sustainable development*. Rio de Janeiro: BNDES, CGEE (November).

Fronzaglia, T., and R. Martins, 2006, “Coordenação de redes de P&D: o caso do sistema de inovação sucroalcooleiro”.

Furtado, A. T., and M.I.G. Scandiffio, 2007, “A promessa do etanol no Brasil”. In *Visages dÁmérique Latine*, n. 5, 95-106.

Hira, A., forthcoming, “Many obstacles, but it will come: prospect for an international biofuels market”.

Hira, A., and L.G. Oliveira, 2007, “Take off and crash: lessons from the diverging fates of the Brazilian and Argentine aircraft industries”. In *Competition & Change*, vol. 11, n. 4, 329-347.

Hira, A., and L.G Oliveira, 2009, “No substitute for oil? How Brazil developed its ethanol industry”. In *Energy Policy* 37, 2450-2456.

Malerba, F., and S. Mani (eds.), 2009, *Sectoral systems of innovation and production in developing countries: actors, structure and evolution*. Cheltenham, UK: Edward Elgar.

FAPESP, Fapesp-sponsored research, May 2009.