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# INNOVATION SYSTEM IN THE BRAZILIAN SUGARCANE AGRO-INDUSTRY

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## ABSTRACT

Ethanol has been recently of great interest worldwide due to two main reasons. First, it is a viable alternative to oil products, used in light vehicles, which price has been substantially raised in the last years. In second place because ethanol is a renewable source of energy and as such, mitigates the emission of greenhouse gases. Although Brazil is losing its leadership of ethanol production for the United States, it is internationally recognized as the leading country to develop its ethanol production from biomass. Differently from the American system which relies on corn as principal raw material, Brazilian ethanol is produced from sugarcane. The Brazilian route shows up as much more competitive and much less pollution contributor than the American one. The objective of this work is to analyze the leading aspects of the Brazilian Innovation System built around the sugarcane industry. The Brazilian success in terms of sugarcane cannot be understood just as based in a natural comparative advantage, but as a result of accumulation of efforts which ended in a positive trajectory of technological learning, relying, mostly, in incremental innovations. That process had, as inflection point, the ProAlcohol Program, launched after the first oil crisis in 1973. From that Program on, the agro industry started the diffusion of innovations making possible constant increases of

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productivity and cost reduction on its production. The technological advance brought benefit to both the alcohol and sugar production; Brazil became the world leader sugar producer. This work is based on the approach of national systems of innovation, according to which the innovative performance of a given country, region or even a sector, cannot be learned by focusing on the efforts and performance of the companies alone. Innovation results from the interaction of players from different institutional nature. To analyze the institutional arrangements as the basis to the innovative process, this work will study the Brazilian efforts on R&D, policies and innovation strategies of main players regarding the country's innovation system in the sugarcane sector, including sugar and ethanol mills, industrial goods suppliers, public and private research institutions and governmental agencies. Given the need to intensify the productive and technological effort to meet the new perspectives of expansion for ethanol production, important changes are to be done in the existing institutional arrangement, where the State needs to have a more active position. This need is being manifested with more clarity recently, given the possibility of launching a new ethanol program. It is also stated the need for the sugarcane sector to make a technological and productive leap, calling the attention for a bigger engagement of the public players for financing and coordinating the innovation efforts for the sector.

## 1) Introduction

Recently, ethanol produced from biomass has been calling the attention worldwide due to two main reasons. First of all, it is a viable alternative to substitute oil products used in light duty fleet vehicles, which prices has risen significantly in the last years. Secondly, because ethanol is a renewable energy source and as such, mitigates greenhouse emission effects.

Although Brazil is second in ethanol production, after the United States (F. O. Licht. 2007), it has raised internationally as the country that has developed the most producing ethanol from biomass. Differently that the American system, based in corn as its raw material, Brazilian ethanol is produced from sugarcane, most of times associated with sugar production. Brazilian route is more competitive and less polluted in terms of generating greenhouse gases that the American one.

The objective of this article is to analyze the main characteristics of the Brazilian innovation system which was structured around the sugarcane agro-industry. The Brazilian success in terms of sugarcane cannot be understood as just a natural comparative advantage, but as the result of a virtuous trajectory of technological learning strongly based in incremental innovations. That process had, as an inflection point, the National Program for Alcohol – Proálcool – launched in 1975 after the first oil crises. From this Program, Brazilian agro-industry started a virtuous path of innovation-diffusion, making possible constant increases of productivity and lowering production costs, both in agricultural and industrial areas. Benefits from technological advances reflected in ethanol and sugar production; Brazil became the first world sugar producer.

This work is based on the approach of national systems of innovation (Lundvall, 1992; Freeman, 1987; Nelson, 1993). According to this approach, the innovative performance of a country, region or even a given sector cannot be captured just from viewing the efforts and the performance of companies individually.

Innovation is a process that results from the interaction of players from the same or different institutional nature. To analyze the institutional arrangement that supports the innovation process, this work surveyed the information on P&D, policies and innovation strategies of principal players of the Brazilian innovation system in the sugarcane sector (mills of sugar and ethanol, capital goods suppliers, research institutes – private and public, and government agencies).

This study is divided in three parts. Chapter one refers to a background of the sector system of innovation, based on the existing literature. The second one brings a description of efforts, strategies and performance of the principal players of this system based on information from the players and secondary sources. In the third chapter we reflect upon the interactive dynamism of the main components of that system.

## 2) Origins of the Sectoral Innovation System

Sugarcane was the first commercial crop of the Portuguese colony. During the 16$^{th}$ and 17$^{th}$ Centuries, the Northeast region of Brazil became the more important producer and world

exporter of raw sugar based in the plantation economy based on slave labor brought from Africa. Although that was a prosperous economy, the linkages for the region were always limited. In the middle of the 17th Century the Netherlanders left the Brazilian Northeast, bringing along the sugarcane crop to the Caribbean. As a consequence, the Brazilian sugar economy receded. Rapidly, new economies emerged in the British, Spanish and French colonies in the Caribbean based on large plantations, thus competing with the Brazilian Northeast, displacing its hegemony as sugar producer. As a consequence, the Northeast region started a secular stagnation process (Furtado, C. 2001).

The Brazilian production system of sugar will suffer a marasmus since then, keeping its economy as a second line exporter. Changes in that system with low productive dynamism will occur only from the 1929 crisis, when Federal Government, emerged from the Revolution of 1930, will help the weak sugar agro industry economy by allocating resources to buy reserve stock and creating the Institute of Sugar and Alcohol – IAA, in 1933. The expanding internal market, due to industrialization, turns to be the natural substitute for the external one. It is the same period that the use of alcohol mixed to gasoline starts. The difficulties with the transportation of sugar, produced in the region lying along the coast, were intensified during the Second War promoted the consolidation of the sugar industry in Sao Paulo, located in the Southeast region. Here, this industry emerges more dynamic, based in modern production techniques, surrounded by an industrial complex which produces industrial equipment and by significant research institutions as the Agronomic Institute of Campinas (IAC) and the Agronomic School of Piracicaba (Esalq).

The Federal Government will try, after the war and through the IAA, to administrate the existing conflict between the weaken Northeast region and the ascending one in the Southeast, separating quotas and defining the production for each region of the country viewing specific markets, ending with the following arrangement: the sugar produced in Sao Paulo will satisfy the Brazilian Center-South market, whereas the Northeast will keep the more profitable external market (Szmrecsányi, T.; Ramos, P. 2006).

The international market for sugar recovers again from the Sixties and the Brazilian Federal Government starts, through the IAA, starts in 1971 the program of rationalization of the sugar agro industry and the national program of sugarcane improvement, the Planalsucar.

The Brazilian sugar supply grows significantly during the first half of the Seventies pushed by exports. However, sugar prices started to fall from the second part of that decade. At the same time the country faced the oil crisis. Federal Government takes a set of measures to figure the problems caused by the excessive oil dependence, imported over 80% and which price had risen four times in 1973. One of the government initiatives is to associate the potential of expansion of the sugarcane industry with the given opportunity caused by the oil crisis, by launching the National Ethanol Program, the Proálcool, in 1975.

This Program had the objective to substitute the internal gasoline consumption by the ethanol produced from biomass. The idea, initially, was to develop more than one crop, such as cassava, but it was sugarcane that soon became the crop with larger potential. To boost ethanol production, Government provided capital, to negative interest rates, for the building or expanding sugar mills, which incorporated annexed units to distillate the alcohol. The production will be multiplied by five, from 664 thousand $m^3$ in the 1976/77 harvest season to 3.7 million $m^3$ in the 1980/81 harvest one. Soon the country's production of anhydrous ethanol will be enough to be mixed to gasoline in the proportion of 15 to 20%.

After this first phase, Federal Government will start, because of the success in producing ethanol and the second oil crisis in 1979, a second investment cycle and multiply by three the internal production until 1985. This time ethanol will be used alone in vehicles specially manufactured for its use. The emerging of a new market for dedicated ethanol vehicles was possible only because the Program relied on governmental fiscal aid for buying new vehicles and controlled prices pledging ethanol profit when compared to gasoline. Government induced Petrobras – the Brazilian Oil Company – and distributors to create the needed systems for storage, transportation and distribution of hydrated ethanol to be used pure in light vehicles. This set of measures, plus financing aids for new distilleries guaranteed that, in a period of five years, production of ethanol exceeded the goal of 10 million $m^3$ established, reaching 11,5 million $m^3$ in 1985 and leading the country to a rapidly growth of its fleet fueled by hydrated ethanol.

The success of the Proálcool hid important difficulties, such as the necessity of high Governmental subsidies to the sugarcane agro-industry in order to assure the expansion of its

productive complex. The return of the democracy and the expanding economic crisis puts an end to the capacity of the Brazilian Government to allocate significant capital flows into new economic activities considered as priorities. The aggravating component of this situation is the so called oil counter shock, in the middle of the Eighties, when oil prices fell worldwide. Soon the fallen of international prices will have an effect in the internal market for the derivates of oil and gasoline. The real price for alcohol, dependent on the gasoline rate, follows the tendency of drop in prices and, at the same time, subsidized aid flows for new distilleries cease.

The stabilization of alcohol production from the Eighties creates an explosive situation. Ethanol internal supply, stagnated, is not capable of satisfying an increasing demand based on controlled prices and subsidies to sales for alcohol cars. The result is biofuel shortage for final consumer at the end of the Eighties, putting the Program into a loss of its credibility. In the beginning of the next decade, Brazil imported ethanol to supply its internal demand.

The shortage ethanol crisis and the extinction of the IAA, executed by the Collor Government in 1990, mark the end of the Proálcool and the beginning of a new stage. Cars fuelled by pure ethanol, which represented 90% of sales of Brazilian light duty fleet in the Eighties, declined tremendously. Equilibrium of near 12 million $m^3$ per year is established between supply and demand and it lasts through the Nineties. The relatively unstable situation counts with two elements. The first one is the recovery of the internal market for automobiles, lead by the 1000 cc fueled with gasoline, mixed with anhydrous ethanol. On the other way, sales of new cars fueled with pure ethanol keep up very low not allowing fleet's replacement. During a certain period these two phenomenon compensate each other; the drop in the consumption of hydrated ethanol or pure ethanol (AEHC) is counterbalanced by the use of anhydrous ethanol (AEAC) (Figure 1). Though, at the end of the Nineties, the quantities of old vehicles fueled by pure ethanol being scrapped surpasses the production of new ones, putting into risk the distribution infrastructure created during the second phase of the Proálcool, of over 25 thousand fuel stations.

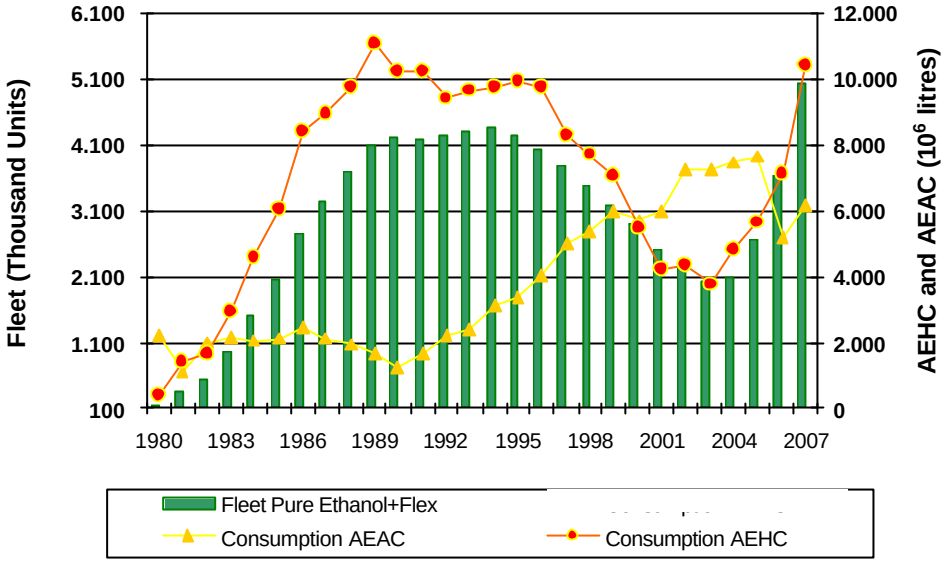


Figure 1: Evolution of Light Fleet Vehicles Fueled with Pure Ethanol (AEHC) and Ethanol Consumption in Brazil (1980-2006)

The important issue to observe is that the relative feebleness of the ethanol market opposes the dynamism of the sugarcane industry which kept its productive expansion though out the decade (Figure 2) (Furtado, A.T.; Scandiffio, M.I.G., 2006). That dynamism is given to the expansion of the sugar market guided by the exports. Between 1992 and 1999, Brazil multiplies per five its sugar exports becoming the world exporter leader. In 2004, the country represents 36.2% of sugar world exports. This great performance on exports is directly related to the dynamism of the sugarcane agro industry which produces in mills annexed with distilleries, having the option to alternate the production of sugar or ethanol, according with the opportunities of expansion offered by those two markets.

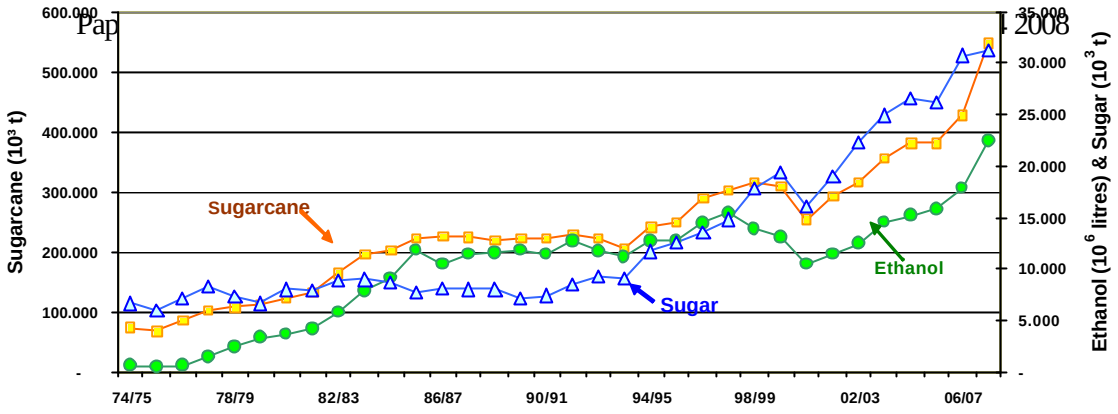


Figure 2: Evolution of Brazilian production of sugarcane, sugar and ethanol (1974/75 to 2006/07)

The ethanol market is growing again, recently, because of the progressive raise on internal prices for oil products. The reduction on price of hydrated ethanol when compared to gasoline made more advantageous the buying of ethanol fueled vehicles. Even though, consumers that had bad memories of the ethanol shortage in the internal market, besides the uncertainties of maintenance of prices would be more advantageous compared with gasoline rates[4], were reticent in buying new ethanol cars.

The solution came in 2003 with the introduction of the *flexible fuel vehicles* (FFV), which can use any proportion of ethanol or gasoline in the same tank. This way, option is given to the consumer who can choose depending on market's fuel price and availability. FFV cars sales success soon reflected on hydrated ethanol production, which increased accordingly (Figure 1). The production of hydrated ethanol had fell to less than 5 million $m^3$ in the beginning of this decade, then reaching 8.1 million $m^3$ in the harvest season of 2005/06 (Figure 3). Keeping the rhythm, the harvest 2006/07 produced 9.8 million $m^3$ of hydrated ethanol. Even though, this level is inferior to the one registered in the Nineties, when production of hydrated ethanol reached near 11 million $m^3$, and maintained the annual volume in approximately 10 million $m^3$ during the first eight years of that decade.

Nevertheless, that recovering in the internal consumption, together with the growth on exports of ethanol, were enough to create a slight shortage of the biofuel in the last period between

[4] Estimated equilibrium price ethanol/gasoline is 70%.

harvest seasons. To minimize that insufficiency, Government decided to reduce ethanol mix in gasoline from 25% to 20%.

Supply of ethanol in Brazil is recovering and surpassed, in 2007, its historical level of the middle Nineties, pushed by attractive internal prices for the biofuel and growing exports perspectives. There are many mills being built or expanded, most of them producing both sugar and ethanol. Investments must increase the country's processing sugarcane capacities of around 420 million tons in 2007, in 80 million tons more, making possible to expand ethanol supply in 4.4 million $m^3$.

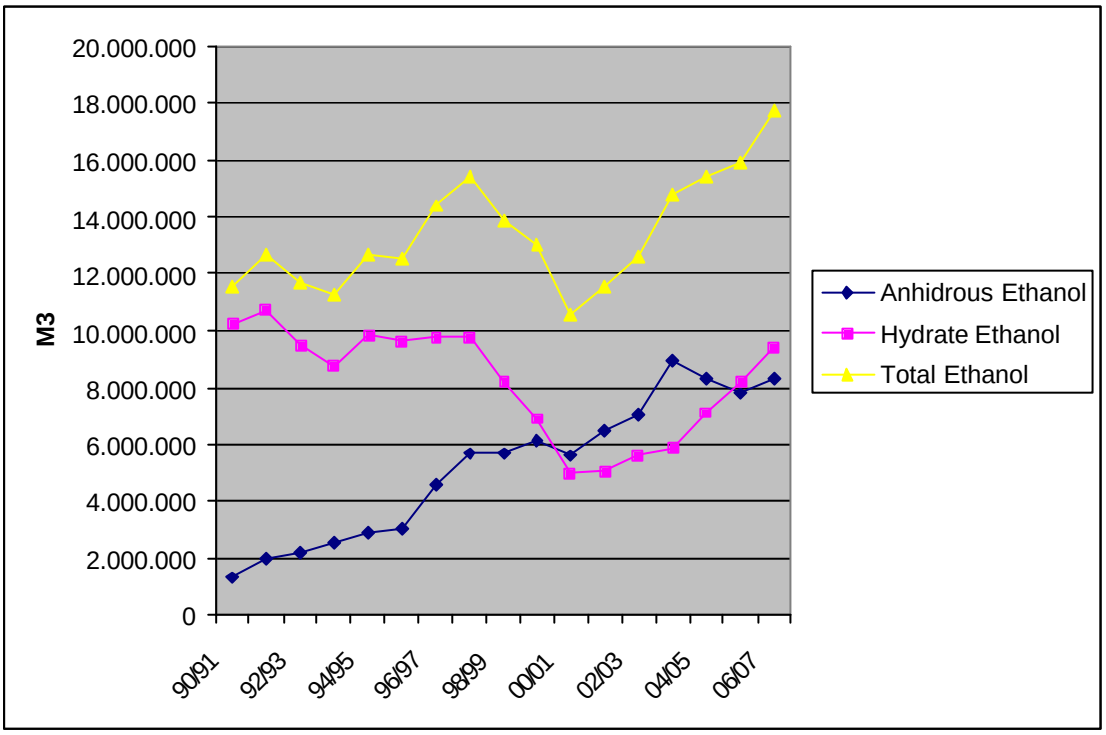


Figure 3: Brazilian production of ethanol (1990/91-2005/06)

Source: UNICA, 2008

### 3) Leading players in the Brazilian Sugarcane Agro-Industry Innovation System

The expansion of the sugarcane production was basically supported by the expansion in the state of São Paulo. The sectoral innovation system for sugarcane production tended to expand

more dynamically in the richest region of the country. And the dynamism of the São Paulo region was based in the conjunction of several factors from which one can detach the abundant good quality natural resources, better transport and energy infrastructure, nearness to the country's biggest market and, above this all, the insertion into a regional system of innovation which converge producers, capital good manufacturers, research institutes and universities. This system made possible that the region experimented gradual increases in the sugarcane productivity from cultivations developed in this same region.

For this reason, the Brazilian innovation system for the sugarcane agro-industry is essentially from São Paulo. This region is the one supporting and sustaining practically all the relevant institutions that act dynamically in that system. The originality of the sugarcane innovation system in Sao Paulo is the supremacy of private research over the public one, although it was not always like this, contrary to the rest of the agro industry.

Brazilian agricultural research is predominantly financed by the public sector. A study conducted by Embrapa (Beintema, N. M.; Avila A. F. D.; Pardey, P. G. 2001) estimated that Federal research institutions (mostly Embrapa) as well as the state ones and universities are responsible for 89% of the Brazilian research efforts on agriculture and cattle-raising. This does not seem to be the situation for the sugarcane sector. The more important sugarcane research center, the Centro de Tecnologia Canavieira-CTC, is a private institution. Federal Government has had a timid action in this area, mostly after Planalsucar was closed, as a consequence of the extinction of the IAA, in the beginning of the Collor Government. Planalsucar had activities regarding genetic improvement in several Brazilian states. Those activities were partially maintained with the support of the private sector.

Following, there are the leader players of the Sao Paulo innovation system.

**The "Instituto Agronômico de Campinas" (IAC) and "Escola Superior de Agricultura Luiz de Queiroz" (Esalq)**

The Agronomical Institute of Campinas (IAC), established in the 19$^{th}$ Century, was initially created to support the coffee cultivation in the state of São Paulo. It was only from the Twenties of the last Century, when sugarcane crop commenced its expansion in São Paulo, that first needs for research emerged. In 1924 agricultural production in the state was

threatened by fast dissemination of the mosaic disease, a plague that attacked sugarcane crops. The fighting to that plague demanded the development of new varieties, more resistant. The Sugarcane experimental station of the Superior Agricultural School Luiz de Queiroz (Esalq), located in Piracicaba, inner the São Paulo state, was created by State Government and had soon a rapid success (Mariotoni, M. 2004). In the Thirties, the experimental station was transferred to the IAC.

From then on, IAC assumed the leadership of the development process for new varieties and modernization of the sugarcane crop within the state. Although IAA counted with more stations in other states of the country, the São Paulo sugarcane agro industry became very dynamic and surpasses, for the first time, the state of Pernambuco in the production of sugar, during the Fifties. The favorable situation of IAC begins to change from the Sixties on, when State Government of São Paulo drops the capital flows for the Institute, getting worst in the next decades.

The Agricultural Institute of Campinas, IAC, will recover its participation only from the second decade of the Nineties with the launching of Procana, an improvement genetic program from IAC. That program will restructure the research activities of the IAC in new bases. There was a decentralization of the program, which now acted in more experimental station, and with contribution of the private sector. The program has become an important success, not only for the launching of new varieties, but mainly for its capacity of introducing new agricultural methods for the sugarcane crop for its associated mills. The IAC program costs R$ 2 million per year and it is financed 60% by the private sector (Hasegawa, M. 2005).

**The National Program for Sugarcane Improvement (Planalsucar)**

In 1972, Planalsucar (Programa Nacional de Melhoramento da Cana-de-Açúcar) established its head-quarter in Piracicaba. This program emerged as intent of improving sugarcane productivity through out the country. In São Paulo, the program had 5 experimental stations. Nevertheless, the contribution of the program was directed to public interest research and low economic return for the State. The research at Planalsucar explored the dominium of genetic improvement and extended to the industrial process area. The advances allowed the introduction of technologies for recycling the vinasse, essential issue for the environmental

viability of Proálcool. Even though, the contribution of the program was limited introducing new varieties of sugarcane in the state of São Paulo (Belik, W., 1985).

Planalsucar played and important roll in other states of the country to accommodate the modern usages for the sugarcane crop. The program opened 30 stations through out the country, 14 in the Center-South regions. Its contribution was also very important to improve sugarcane productivity in the Northeast states. There were more experimental stations in the state of Alagoas (Northeast) than in São Paulo.

Planalsucar was dismantled right after the extinction of IAA, in 1990. Its activities were incorporated by Ridesa.

**The Inter University Network for the Development of the Sugar-Ethanol Sector (Ridesa) –**

Ridesa (Rede Interuniversitária para o Desenvolvimento do Setor Sucro-alcooleiro) is formed by Federal universities, and it is a company created with the purpose of incorporating the activities of the extinguished Planalsucar, by giving continuity to the development of researches viewing the sugarcane genetic improvement. The network was agreed and signed by seven Federal Universities (UFPR, UFSCar, UFV, UFRRJ, UFSE, UFAL and UFRPE) located in the same areas where former Planalsucar was. Technical staff was absorbed from Planalsucar and infrastructure from head-quarters and coordinator branches from the experimental stations. With the support of a significant part of the Sugar-ethanol Sector, through covenant, the network started its functions in 1991, taking advantage of the staff capacity and the regional bases of the extinguished program, to which were joined professors from the universities.

Ridesa counts with 31 experimental stations to development its research; those stations are strategically located in seven states of Brazil, where sugarcane has important expression. Besides those experimental stations, the network develops also research within the campus of the seven Federal universities, in different graduate courses, mainly for master and doctorate levels.

Ridesa continued the Genetic Improvement Program for Sugarcane (Programa de Melhoramento Genético da Cana-de-açúcar (PMGCA), which still uses the code RB to identify its cultivations; the PMGCA released 65 varieties. Ridesa, as a company, accomplished significant success developing varieties and competed with the program from Copersucar in the release of sugarcane varieties. Those RB varieties are responsible for 57% of cultivated sugarcane area in the country. Resources for the program are limited and come basically from private initiative.

**The Center of Technology for Sugarcane (CTC)**

Copersucar (Central Cooperativa de Produtores de Açúcar do Estado de São Paulo) was created in 1959 as the fusion result of two regional co-operatives. That co-operative expanded rapidly, participating with 51% of the sugar market share in the country (Mariotoni, M. 2004). That co-operative felt no interest from IAA to promote genetic improvement programs. Pursuing a change in that situation because it did not help the local agro industry Copersucar invited, in 1968, the Hawaiian geneticist Dr. Mangelsdorf to structure a program for genetic improvement. This was the basis for the creation of the Research Center Copersucar.

The Copersucar Center of Technology (CTC) was created in 1970 in Piracicaba. It started, initially, competing with the IAA experimental stations, which had more favorable conditions than CTC. Rapidly, technical assistance for the associated mills will become an important revenue for the Center. This experience on mills maintenance will define the Center's important roll as an improvement leader in the processes for the industrial area.

The capital goods industry had a low technological capability during the period before the Proálcool. When investments of significant amounts were made deriving the Program, the incorporated technology in the equipments was obsolete. The function of CTC was basically to introduce incremental innovations that allowed improve the efficiency of the extraction and fermentation processes from sugar syrup. Those incremental innovations were decisive to increase the level of sugar extraction, which increased from 92%, before the Proálcool, to 96% in the middle of the Eighties (Mariotoni, M. 2004).

During the Eighties, the new varieties program will start to yield good results. The varieties used in the state of São Paulo that had come from other states of Brazil and from Argentina

started to be substituted by the ones developed by CTC. From then on, CTC varieties became predominant both in the São Paulo state and the country scenarios.

In spite of the great success accomplished by CTC, Copersucar faced growing financial problems mostly due to strong fluctuation on *commodity* prices in the international market. CTC associates were reticent in financing the Center. As a consequence, the number of associates, more that 70 mills during the prosperous period of the Co-operative, fell to less that 40 at the end of the Nineties. The technologies developed by the CTC, although were extremely important to assure the sector profit and constant increase on productivity, were easily appropriated by the non-co-operates. Copersucar ended on dissolving the CTC, which became the Center of Sugarcane Technology, in 2005.

The CTC (Center of Sugarcane Technology) is an institution that counts with a budget of 45 million Reais (Brazilian currency) and 107 researchers.

**The capital good industry – the Dedini case**

The capital good industry associated to the sugarcane agro-industry emerged basically within the state of São Paulo. The principal manufacturer is Dedini S.A., a joint-stock company, which is also the leader supplier for industrial equipment to mills and distilleries. Installed in Piracicaba, Dedini started its activities in the Twenties, attending the maintenance demand from the existing mills. With the country's growing industrialization process, from the Thirties, Dedini started to produce complete equipments; at the beginning, they were small sugar mills and afterwards, modern mills. The public property technology practically did not change until the Proálcool was launched.

The growing demand for technological innovations, induced by the qualified demand form the São Paulo Agro industry lead Dedini to change its technological profile. Since 1980 until May of 2007, Dedini placed 60 patent or utility models to INPI, the Brazilian National Institute for Industrial Property. A quantitative analysis of those deposits allows establishing that patent activity was very intense during the Eighties, or during the Proálcool period, but it suffered a strong decline through out the Nineties. Only in the beginning of this decade patent activity will restart (Table 1).

**Table 1: Dedini's Patent deposits for Invention and Utility Models to INPI**

| | 1980-1989 | 1990-1999 | 2000-2006 |
|---|---|---|---|
| Patent | 27 | 7 | 11 |
| Utility Models | 11 | 3 | 1 |

Source: INPI (2007)

Dedini was supported by Fapesp (Fundação de Amparo à Pesquisa do Estado de São Paulo), a Foundation that supports research in the state of Sao Paulo, to industrialize, in a pilot plant, the hydrolysis process from sugarcane bagasse. That process represents an important opportunity for Brazil to develop the hydrolysis technology for the production of ethanol.

**CanaVialis and Alellyx**

In 2003, the investment fund from Votorantim Ventures decided to invest 25 million Reais to create a biotechnology company, named CanaVialis. The company was formed by a researchers group from the Federal University of São Carlos with large experience in genetic improvement for sugarcane. Those researchers shared the program of genetic improvement of Planalsucar during the Seventies and now formed this company with the defined objective of moving from the traditional model of sugarcane genetic improvement to a new one based on biotechnology. Alellyx is responsible for the biotechnology activities, and is also supported by the Votorantim Fund.

CanaVialis counts with two experimental stations, one located in the state of São Paulo and the other in Paraná, and a crossing and seedling producing station in Alagoas. This infrastructure was a Planalsucar legacy. The company has signed contracts with 34 mills; from those, almost a half belongs to Grupo Cosan, the large sugar-cane group in Brazil. CanaVialis activities are held in an area of 593.5 thousand hectares, producing 54 million tons of sugarcane, which is equivalent to a production of 5.2 million tons of sugar or 1.8 million $m^3$ of

ethanol)[5]. CanaVialis improvement program is considered, nowadays, the largest program in the world with 1.5 million plantules a year obtained from hybrid seeds produced in its own crossing station located in Maceió, capital of Alagoas.

Alellyx is a company dedicated specifically to genetic research. Supported by Fundo Votorantim; its research goes beyond sugarcane, including orange and eucalypt. In partnership with CanaVialis, Alellyx research new varieties, which are developed with the use of biotechnology. According to Valor Economico Journal, the two companies invest annually near US$ 40 million. The goal is to use the genetic engineering to develop varieties with better productivity index, more resistant to droughts and to plagues. The Alellyx researchers' team counts with 110 professionals, from which 22 hold a Ph.D. and 17 are Master's degree.

**Supporting Agencies (Organisms)**

Since the extinction of the IAA there has been a significant reduction in the support from public agencies for sugar cane R&D. The Sectors Funds (Fundos Setoriais) were created from 1999 to supply some needs emerged as a consequence of neo liberalism reforms that partially destroyed the Brazilian innovation system. However, none of those Funds would act specifically in the sugarcane arena. A survey made on the Prossiga[6] database, which contains all projects on the Prossiga base reveals that only 81 of them or 0.5% answers to keyword "sugarcane". (Table 2).

[5] Valor Econômico Journal. Edition dated 6/9/2006.
[6] Prossiga: Brazilian database Program of Information for Science, Technology and Innovation Management.

**Table 2: Projects of Sectors Funds (1999-2006)**

| **Funds** | **Keyword: biomass** | **Keyword: sugarcane** | **All** |
|---|---|---|---|
| | | | |
| CT – Energ | 46 | 14 | 1.661 |
| CT – Agronegócio | 5 | 6 | 1.295 |
| CT – Hidro | 4 | 21 | 1.776 |
| CT –Petro | 2 | 7 | 2.932 |
| CT –Infra | 1 | | |
| CT –Verde e Amarelo | 1 | 3 | |
| CT –Transversais | 1 | 7 | 1.376 |
| CT –Info | 1 | 9 | 2.769 |
| CT – Biotecnologia | | 3 | 261 |
| CT –Saúde | | 7 | 1.137 |
| CT –Mineral | | | 265 |
| CT – Transporte | | | 67 |
| CT –Amazônia | | | 61 |
| CT – Aeronáutico | | | 51 |
| CT – Espacial | | | 33 |
| CT – Funttel | | 4 | 33 |
| CT – Aquaviário | | | 7 |
| **Total** | **61** | **81** | **14.779** |

Source: based on Prossiga data, extracted in 22/12/2006.

On the other hand, Fapesp has shown great concern with the sugarcane sector and supported the Genome Cane project, as a part of the genome program. This project began in 1998 and has already identified 50 thousand cane genes. It is a remarkable example of mobilization of public resources with intense participation of Universities and Public Institutes in the execution of guided basic research. It is possible that strong correlation exists between the amounts of capital Fapesp allotted and the competitiveness of the Sugar and Ethanol Sector in

São Paulo. Fapesp programs are important initiatives and are behind the Alellyx and CanaVialis enterprises in the biotechnology arena.

**4) The Interactive Dynamism of the Sugarcane Agro Idustry Innovation System**

Players of the innovation system in the sugar agro-industry had shown an important capacity of interacting. However, those initiatives had occurred apart from the Government ones or the public ones, contrary to the rest of the agriculture where public research prevails. The presence of the private sector is a central aspect of the existing interaction in the sugarcane system, which occurs both for the problems solving side as for the financing and executing the research one.

The first form of interaction consisted in a co-operation among the CTC researches in terms of industrial processes and the capital goods industry after the Proálcool. The pressure roll and Donnelly shutter technologies (millstone feeder) were transferred and adapted by CTC and then sent to capital goods manufacturers in Brazil. Those technologies allowed an important improvement in the extraction of the sugarcane juice.

As CTC consolidated as an important center for generating technological knowledge for the sector, there was a growing participation of other players in the innovation process. As an example of CTC importance, one can mention the development of the biopolymeric technology, in the Nineties, in co-operation with the Institute of Technological Research, the IPT from the State of São Paulo. The CTC was also very important for the co-operation in the agronomic research field. The Cane Program from IAC has collaboration with CTC in the field of development of new varieties and uses the experimental station of this Center to accomplish the crossing of new seedlings.

Ridesa, the company that inherit the Planalsucar program, illustrates the intense interaction that exists between the agronomic research produced by the Universities and the productive sector, which sponsors, significantly, the program. The same engagement from the productive sector can be noticed in the Programa Cana from IAC, which has the support of private initiatives, mainly the program partners mills, but also raw material producers and co-operatives, to finances research activities.

The kind of system constituted after the decline of the State intervention in the sector, has a leading presence of the private sector regarding the research financing and in the application of new technologies. This system has demonstrated a remarkable productive dynamism which allowed the sugarcane crop to expand regularly whether for the production of sugar or ethanol.

Until recently, the sector's productive evolution was marked by the remaining elements of the productive basis formed during the State period, above all, thanks to the Proálcool. The interactive dynamic, constituted between the private sector and the acting institutions before the public programs, allowed that competences were not put to scrap. On the contrary, there was a reorganization of the public agronomic research that increased its capacity to solve problems and transfer technology to the productive sector. Although, this interactive dynamic is associated only to an incremental innovative dynamic. Thus, it is not capable of facing the emerging technological challenges of the bioethanol.

Demands from the internal market and export expectations set a bigger challenge. The external market itself has an enormous potential for expansion. If Brazil happens to substitute 5% of the world demand of gasoline by ethanol, within twenty years, this means that the country would need to multiply by four its sugarcane production. Still, the needed area and cane production to meet this goal could be reduced with the introduction of new technologies. The productive leap for sugarcane production that Brazil foresees will demand a disruption within the technological path that guided the evolution of the sugar and ethanol agro-industry.

Fapesp has answered positively to this need, sponsoring projects on disrupted technologies combining public research with the private one. Besides the cane network above mentioned, Fapesp financed the industrialization, in pilot scale, for the process of rapid acid hydrolysis, patent from Dedini. This project is a partnership between the CTC and Dedini within the Fapesp PITE projects, which started in 2002. More recently Fapesp consolidated its leadership in the coordination of technological innovation efforts for the sugarcane sector, pursuing the implementation of a program viewing the development of the cane technology and its by-products. As a first initiative for this program, Fapesp and Oxiteno (a chemical products company) launched a calling for research projects for both acid and enzymatic hydrolysis. The projects, to be executed by research institutions from the state of São Paulo will be financed by Fapesp and Oxiteno, following the established principles of the PITE program from

Fapesp. A second initiative was launched with Dedini in the purpose to develop the acid hydrolisis technology or new technologies, the electricity production from sugar-cane byproducts, energy efficiency in the industrial process, and efficiency gains in the distillation and fermentation processes. The Dedini-Fapesp wil destinate 100 millions reals in a 50/50 share, for a 5 years period to finance Industry-University research partnerships.

More recently Fapesp launched the Bioen program for promoting ethanol technologies. The program has 5 main issues. The first one is to promote genetic improvement of sugar-cane varieties. The second one is the ethanol production process. The third is the use of ethanol in car engines. The fourth is the research in biorefineries and alcohol chemistry, and the fifth is on the social and environmental impacts of the bioenergy fuels. The public call amounts 38 millions reals, half from Fapesp, and the other half from Federal Agencies, mainly CNPQ (National Research Council) and Pronex, from the Ministry of Science and Technology.

## 5) Final comments

The sectoral system of innovation for the sugarcane agro industry was formed centered in the São Paulo region, when production of sugarcane leadership was progressively transferred from the Northeast region to this state. The Federal Government was prominent in the development of the sector's economic activity through the IAA and the Proálcool production and prices controls . The modernization of the sugar and ethanol units was extensively supported by the IAA resources and the Proálcool mobilized a volume of investments without precedent, with interest rates subsidized for the sector.

Regarding research, the Planalsucar was an important step to create a research base for the sector, besides to modernize the agricultural practices. Before this, IAC had a remarkable roll in the development of agronomic research in São Paulo. The crisis of this model, crystallized with the extinction of the IAA, did not represent the disarticulation of that system. On the contrary, the sectoral system of innovation responded dynamically, increasing the expenditure and the participation of the private sector in the execution of the R&D. This major engagement increased the efficiency and interactivity in the innovation system. However, this is consistent with the technological path supported on incremental innovations, which was successful to increase productivity and production, backed on the existing technological base.

The challenges that are being placed due to the expansion perspectives for the ethanol production are much bigger. The displacement of sugarcane production to other states but São Paulo, the leadership of alcohol production over sugar and, above all, the need to increase even more the productivity of the sugarcane productive system place technological challenges that cannot be met from initiatives supported just by the financial resources from private players. Even because lately, the private sector has suffered some weakness due to the undue appropriation of the investment results (gains) manifested in the CTC separation from Copersucar.

This new stage of the sugarcane agro industry innovation system is responsible for retaking the leadership of the public sector, both for financing and coordinating the efforts, to guarantee the execution of the targets in medium and long term productive expansion. The state of São Paulo is assuming this roll though Fapesp. Even though, given the national dimension of the challenge being placed, the Federal Government should be engaged in a more incisive way with a technological program centered in the expansion of the ethanol production to give a broader previsibility to the leading players on which they could converge to take their enterprises decisions.

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