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BioEnergy Brazilian Program (BIOEN) Innovation Networks

Subtheme S5 - Government and public policy in the Triple Helix era.

Abstract

This article investigates the ex ante appropriability pattern for the Brazilian BIOEN – BioEnergy - Program, a multidisciplinary ethanol sugarcane project. The economic issues, assets management and social network formation together with scientific and technical perspectives will all be investigated.

Networks of patent citation are used for technological foresight of ethanol research and to build development scenarios.

The project's goal is to formulate an organizational design: a) analysis of the demands due to intellectual property of technologies, supplies and genetic material that can create risk situations for the continuity of the program itself; b) preparatory analysis of business plans and economic exploration 'models', from intermediate products and supplies to final products. This includes an incentive system, and scenarios of partnership formation, from the formation of networks that identify patent families, networks of quotations on intellectual property attribution and appropriability patterns in plant biotechnology; c) *ex-ante* impact evaluation for the formulation of business plans based on the research results.

The foresight proceedings are under construction, given that BIOEN is a 4 year project. Preliminary results consider a lexical query composed of a combination of BIOEN R&D areas and International Patent Classification areas (C07h21 and C12N in the "title", "abstract" and "claims").

This paper evaluates the "macro-level" scenario of the freedom-to-operate BIOEN system, looking for "ethanol and/or bioethanol" patent networks.

This first part of the investigation has demonstrated that the sugar cane business has an important technological and appropriation pattern that has opened up demand. Many technological

trajectories, however – including corn ethanol and sugarcane ethanol production – seem to be defined.

Especially for the use of non-saccharified biomass involving enzymes, anaerobiotics fermentation and biorefineries technological capabilities, the BIOEN Project will have to pay attention to freedom-to operate systems of contracts with global entreprises.

Keywords

innovation networks, governmental innovation management, biomass, ethanol, technological appropriability, freedom-to-operate.

Introduction

Ethanol has become a global strategic fuel and a widespread alternative to climate change challenges. Areas such as carbon and energy balances and greenhouse gas emissions gain special relevance. Brazil has a concrete chance of becoming a leader in biofuel production in the next decades. However, one needs to better understand local and global market structure changes, and the conditionings behind rates and patterns of bioenergy diffusion. Particularly, the institutional set of incentives and rules adopted (or not adopted) as industrial public policy in Brazil, deserves attention.

The expansion of ethanol in Brazil combines productive gains based on new technologies and the increase of the planted area of sugarcane. Increasing growth rates could generate negative impacts on the environment, social relations and other economic activities. It is important to analyze the risks and to propose specific methods or policies in order to avoid these impacts[1].

In this context, the BIOEN Program[2] is a broad and multidisciplinary ethanol sugarcane project, from its scientific demands, technological perspectives, economic issues, assets management and social network formation.

It is lead by the following areas:

1. Biomass Research: sugarcane and plant improvement and farming
2. Ethanol Industrial Technologies and Processing Research
3. Alcoholchemistry and Biorefineries
4. Engines: ethanol for motor vehicles: otto cycle and fuel cells
5. Impacts Research: social, econommic, environmental studies, land use and intellectual property.

This article is part of the “impacts research” of BIOEN, “Organisational Design of the BIOEN Programme: Intellectual Property, Incentive Mechanisms and Impact Evaluation” project, a broad-based economics and business investigation to support ethanol incentives, industrial efforts and market competitiveness. Therefore, it does not evaluate “impacts research” perspective, as this is not a technological field.

The following paper will analyze the technological development situations related to BIOEN, from the perspective of the global economy based on knowledge and technological foresight.

The intention is to identify the technological trajectories and predict the development of technologies that could become important in terms of the freedom-to-operate program.

It is connected to the field of intellectual properly studies, in the sense that competing standards of the economy based on knowledge can be understood, and strategies can be formally designed based on the investigation of patent production.

The study builds networks of patent citations and then un-builds them, analyzing the relationships of technological content between groups of technologies.

These results, although partial, allow the evaluation of the market potential of groups of emerging technologies to take place for the set of topics and sub-topics that make up the BIOEN program, strengthening organizational design studies and opening up the possibility to predict policy-making.

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[1] http://bioenfapesp.org/index.php?option=com_content&view=article&id=69%3Aimpacts-research-overview&catid=42%3Aimpacts&Itemid=66&lang=en

[2] From The State of São Paulo S&T Agency, FAPESP.

State of the Art

The Bioen Program has a solid core for supporting academic exploratory research related to these topics. It is expected that these exploratory activities will generate new knowledge and help develop scientists and professionals essential to the advancement of industry capacity in ethanol related technologies.

Brazil is well ahead of most developing economies in research applied to the development of agriculture and agribusiness, as noted by Silveira et al (2007), and Fonseca et al (2007).[3]

Knowledge communication, which supports the discussion of technology networks and links it with questions of merit and approval (Dal Poz, 2007; Cowan & Jonard, 2007), appears in the simplified form of a division between integrated and unintegrated research structures which, besides defining a rule for the sharing of gains (alpha percentage not dependent on the amount of total revenue earned), involves a variable relating knowledge transmission from the research unit (creator of the invention or new knowledge) to a firm that intends to develop it in a second stage. Two conclusions are obtained: (a) an integrated structure facilitates knowledge diffusion by reducing the percentage to be paid to the research unit; and (b) if an unintegrated structure persists, a system of intellectual property is required to avoid the dissipation of earnings determined by ex post competition. According to Aghion & Howitt (1998), the system failure represented by the Brazilian patent regime, does not recognise gene patents. This is a matter of paramount importance to BIOEN.

The indication given by Aghion & Tirole (1995) that integrated units are more conservative corroborates the suitability of the BIOEN strategy while at the same time extends the technology paradigm from applied molecular biology to bioenergy and increasing the scope to negotiate technology with economic agents.

Studies on the industrial organization pattern (Cowan, 2005) rely on methodologies to understand how a certain industry or sector integrates demands for multiple knowledge (Marsili, 2005) in order to obtain a new technical artifact. Such integration results in horizontal or vertical relations, alternating the connection and disconnection of actors, in an evolving dynamic of such arrangements and their configurations.

The actors establish links starting from the forward citation of patents. Investigating them reveals the interests - including the latent ones - the geography of such arrangements and their games of product differentiation, as well as the dynamics of the sector innovation.

Such evolutionary organization into innovation networks may allow the entrance of new actors - such as developing countries.

Network designs vary according to the efficiency of the mechanisms for communication among the various agents involved in the research organisation (Bolton & Dewatripoint, 1994; Bolton & Dewatripoint, 2007). More hierarchical forms increase the levels required for communication among research interfaces, while organic forms require agents with multitasking competencies. Based on this type of formulation, Aghion & Tirole (1995) discuss how to define authority and decide on an appropriate division of labour between core and periphery, with a cutoff value determined by the principal's ability to monitor the agents involved in the contractual research process. They argue that there is a tradeoff between initiative and loss of control of the research system: "the more the principal supervises, the lower the agent's effort" (Aghion & Howitt, 1998:476).

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[3] Brazil is considered to have built an agricultural research system that has made it a "super NAR", i.e. Brazil's national agricultural research system is superior to those of most developing countries and comparable to those of some developed countries, with strong participation in the international markets for agricultural products as well as renewable energy (Traxler, 2000).

Research Focus

To consolidate biofuel production one needs to understand the local and global market, patterns of bioenergy diffusion, institutional incentives, rules and industrial public policies. The expansion of ethanol production in Brazil, for instance, will combine productive gains based on new technologies and increase the planted area of sugarcane. Fast rates of growth could generate negative impacts on the environment, social relations and other economic activities. It is important to analyze risks and to propose specific methods or policies to minimize these impacts. Additionally, while ethanol becomes a global strategic fuel and a widespread option to help with issues related to the challenges of global climate change, topics such as carbon and energy balances and greenhouse gas emissions gain special relevance.

This paper investigates specifically the ex ante appropriability pattern for the BIOEN Program, through a technological foresight approach: the networks of patent forward citation indicators.

The BIOEN project's goal is to formulate an organizational design: a) analysis of the demands due to intellectual property of technologies, supplies and genetic material that can create risk situations for the continuity of the program itself; b) preparatory analysis of business plans and economic exploration 'models', from intermediate products and supplies to final products. This includes an incentive system, and scenarios of partnership formation, from the formation of networks that identify patent families, networks of quotations on intellectual property attribution and appropriability patterns in plant biotechnology; c) *ex-ante* impact evaluation for the formulation of business plans based on the research results.

The research focus was tailored on the idea that BIOEN establishes partnerships with industries for cooperative R&D activities between industrial laboratories and academic laboratories at universities and research institutes, which are to be co-funded by FAPESP and industry.

Networks of innovation approach are used as foresight tools to predict BIOEN potential intellectual property patterns. R&D technologies involve techniques of biological markers, viral vectors for introduction or genetic engineering (Dal Poz, 2006). The objetives of BIOEN are:

- To search for and select technological trajectories of plant varieties;
- To define patterns of market interests;
- To develop a network tool which can be accessed byBrazilian R&D institutions in order to protect efficiently the technological results of the BIOEN and to identify strategic behaviors of appropriation.

Methodology

This paper deconstructs the technological content of IP aspects for innovative arrangements of BIOEN, in order to understand its technological dynamics.

According to literature on industrial arrangements, the actors interests in the assets based on technology result in the building of innovation networks.

Networks of patent citation are used for technological foresight of ethanol research and developing new scenarios.

Binenbaum (2008) has contributed by combining the substantive and operational levels to configure a methodological proposal in which the concept of governance is specified by the idea of the role of leadership in research consortia with a broad social objective. His reference point is the logic of collective action involving the fundamental characteristics of R&D activities (public goods, complementary assets and returns to scale and scope).

The investigation goal is a freedom-to-operate condition. So, relevant technological trajectories must be analysed, not only patents and patent groups. The R&D efforts – all over the world – are being used to draw up innovation scenarios for BIOEN.

The methodology is based on forward citations that a patent receives, which are indicators of innovative strength of markets based on technology. Highly cited patents are proxies for technological market values. The methodology is based on forward citations received by patents.The citations' relationships create the network.

According to Hall *et al.* (2005), patents may be considered as reliable sources of innovation studies and technical change. Sampat and Ziedonis (2002) show the economic and technological importance of such analysis. Trajtenberg (1990) and Jaffe & Trajtemberg (2002) claim that the measurement of forward citations received by a patent is an innovation indicator.

The deconstruction of network structural relationships – by market agents' citations - reveals the technological trajectories and the emergence of others[1]. It enables the understanding of the coordination means and the R&D intrinsic efforts - vis-a-vis the activities involving invention protection.

The mapping of such movements reveals how the dominant technological trajectories - or paradigms - are constantly changed by incremental innovations, whose direction and development are mostly determined by the paradigmatic trajectories. Such interdependent development has been called, in literature, technological trajectory (Dosi, 1982).

Technological foresight - as part of the future studies field - is the methodological tool to understand the technological development and comprehend its dynamics.

Network indicators – such as network density, patent centrality and geodesic distance - bring a new perspective to the innovative dynamism measures. A certain company A may have fewer patents than B, but it may be cited by other companies which may also be highly cited. They offer a non linear view on a company´s innovative capabilities and its technological potential. Citation indicators of a patent, which are used to understand the relationships among actors and their connectivity levels, are, according to Breschi & Lissoni (2004): centrality, geodesic distance and connectivity.

The technological trajectories defined by such technological arrangements result from the use of a methodology, which shows the scientific contents of inventions, the technological accumulation pattern and diffusion index on the market; the role of certain technological artifacts in trajectories; the composition of technological subcomponents and their roles in the consolidation of certain trajectories; the industrial actors governance strategies, through investments, buying, merging and technological licensing.

The search for information on patent networks started from key-questions (Zhu *et al*. 1999) which aimed at understanding the investigation objective in order to reach the survey goals. The query consisted of a combination of the topics shown in Chart 1.

The network was constructed from lexical-based queries, combining International Patent Classification (IPC) classes C12N and C07h21, the International Classification biotechnological group.

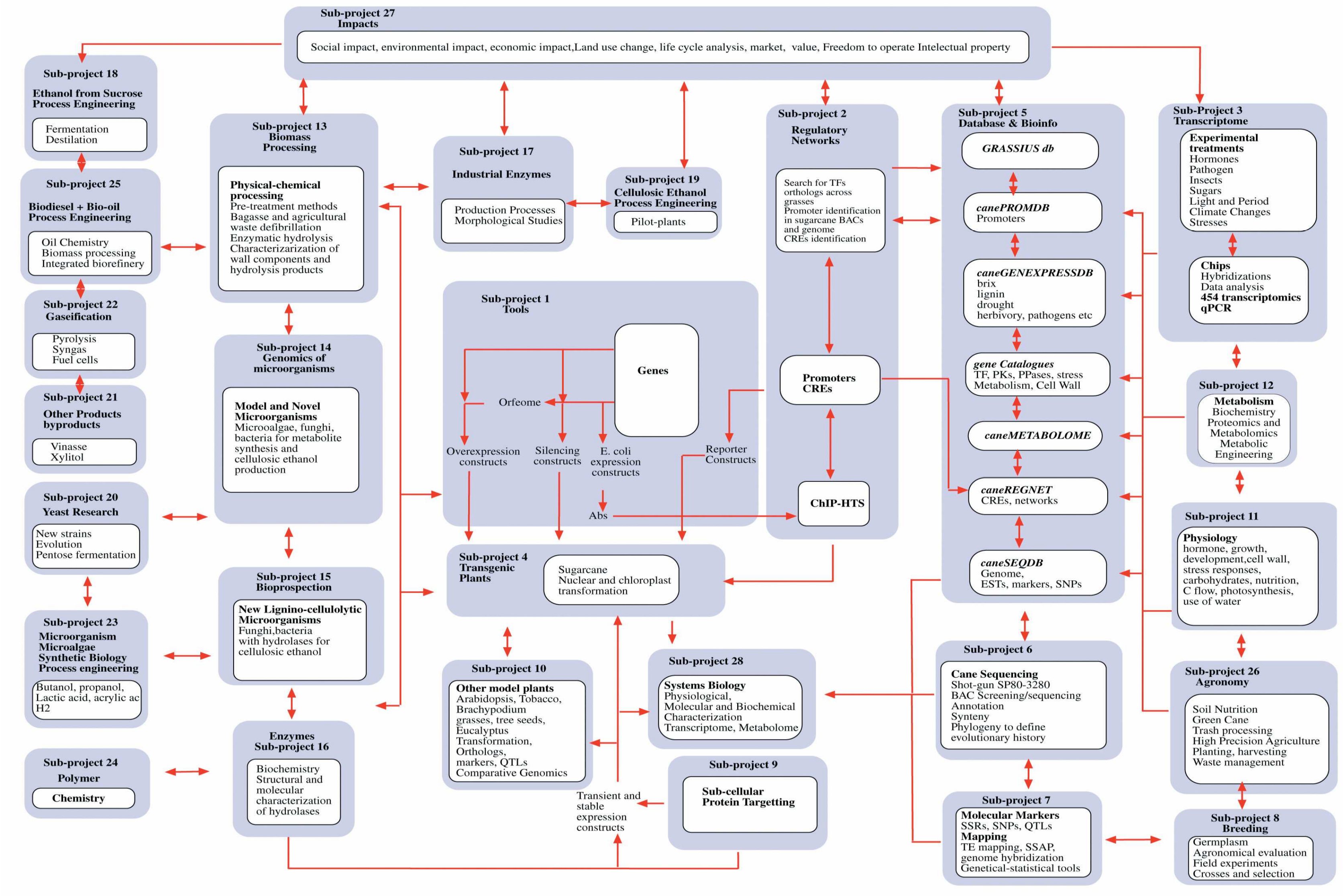
This paper presents only the "macro-level" investigation for BIOEN, which must have more specific terms – including a meso-level and a micro-level of technological demands, looking for macro-lexical patterns of patent contents.

The patent search was driven by a lexical query composed of combinational BIOEN R&D macro term areas (Chart 1) and International Patent Classification areas (C07h21 and C12N in the "title", "abstract" and "claims") for the following biotechnological areas (Table1).

Chart 1 - Combinatorial terms search matrix.

IPC class	Patent Field	Key-word
C12N/C07h21	Title	Ethanol or bioethanol
C12N/C07h21	Abstract	Ethanol or bioethanol
C12N/C07h21	Claims	Ethanol or bioethanol

Graph 1 BIOEN Research Areas



Source: FAPESP, The State of São Paulo S&T Agency.

Table 1 – Biotechnological areas of BIOEN

1. Enzymes	**Enzymes Engineering**	**Biomolecular foresight for biomass use**		
2. Fungus	**OGM**	**Fungus or other microroganisms enzymes structure and function**	**Productions processes and/or productivity**	
3. Plant fisiology	**Plant resistence (water and nutrition)**	**Plant diseases responses**	**Biomass productivity**	
4. Gene expression	**Plant transformation**	**Plant new varieties**	**Biomarkers**	**Gene expression**

The network presented is the result of the intersection of the ethanol or bioethanol (title and abstract and clemims) and C12N query.

Network indicators[4] – as density and geodesic paths are used to understand the network structure.

The network patent lexicographical contents were analysed according the above biotechnology areas (Table 1).

Odysseýs Patent Computacional System[5] for Information Retrieval is used for forward citation searches, selections, aggregating data from the *United States Patent and Trade Office* (USPTO), and identifying networks by algebraic indicators.

Findings

The foresight proceedings are under construction, as BIOEN is a 4 year project and has a very complex R&D structure to be investigated. Preliminary results consider a lexical query composed of a combination of BIOEN R&D areas and International Patent Classification areas (C07h21 and C12N in the "title", "abstract" and "claims") for enzyme characterization, process engineering, gene expression, cell and molecular biology and fermentation yeast enzymes.

The citation network (Figure 1) is the full image of patent citations. Sub-networks A and B are the most important clusters of the appropriability scenario represented by patent citation relationships.

The low global density (Table 2) demonstrates that this ethanol network is not a very dynamic cluster of R&D industry efforts, as density is especially relevant to know how a knowledge area has been seen as a technological opportunity for industry.

Table 2 - Networks Densities

Network and Subnetworks Densities	**General network**	**Sub-network A**	**Sub-network B**
	0,4608%.	**0,7619%**	**1,7304%**

[4] Such as network analysis literature points.
[5] Developted by Fabio Kenji Masago at an institutional partnership among the authors of this paper.

Given the geodesic distance indicator (Chart 2) it is possible to infer that the cohesion between the most highly cited patents is not strong, and that continuity between them is rare. For BIOEN this means that there is a hiatus in terms of patent appropriation. However, to really understand which technological areas can and must be protected, the lexicographic content of the patents of networks A and B were analyzed.

The technical fields of Table 1 - Biotechnological areas of BIOEN – were used as the analysis parameter, comparing them with the inventions of patents with a high level of citation and its citers.

Sub-network B (Figure 1) concerns determination of ethanol in an aqueous test sample for medical diagnostics industries, and it is out of the fuel and biorefineriy R&D scope.

Sub-network A (Figure 1) content analysis is shown in Table 3. All cited and citing patents were analyzed from their lexical contents perspective, and classified from a BIOEN freedom-to-operate perspective.

Network patents that had expired (up to 1990) were analyzed too, taking the same technological contents and assignee name: 98% of them have new patents, demonstrating continuous efforts of those patent assignees in the technological trajectory.

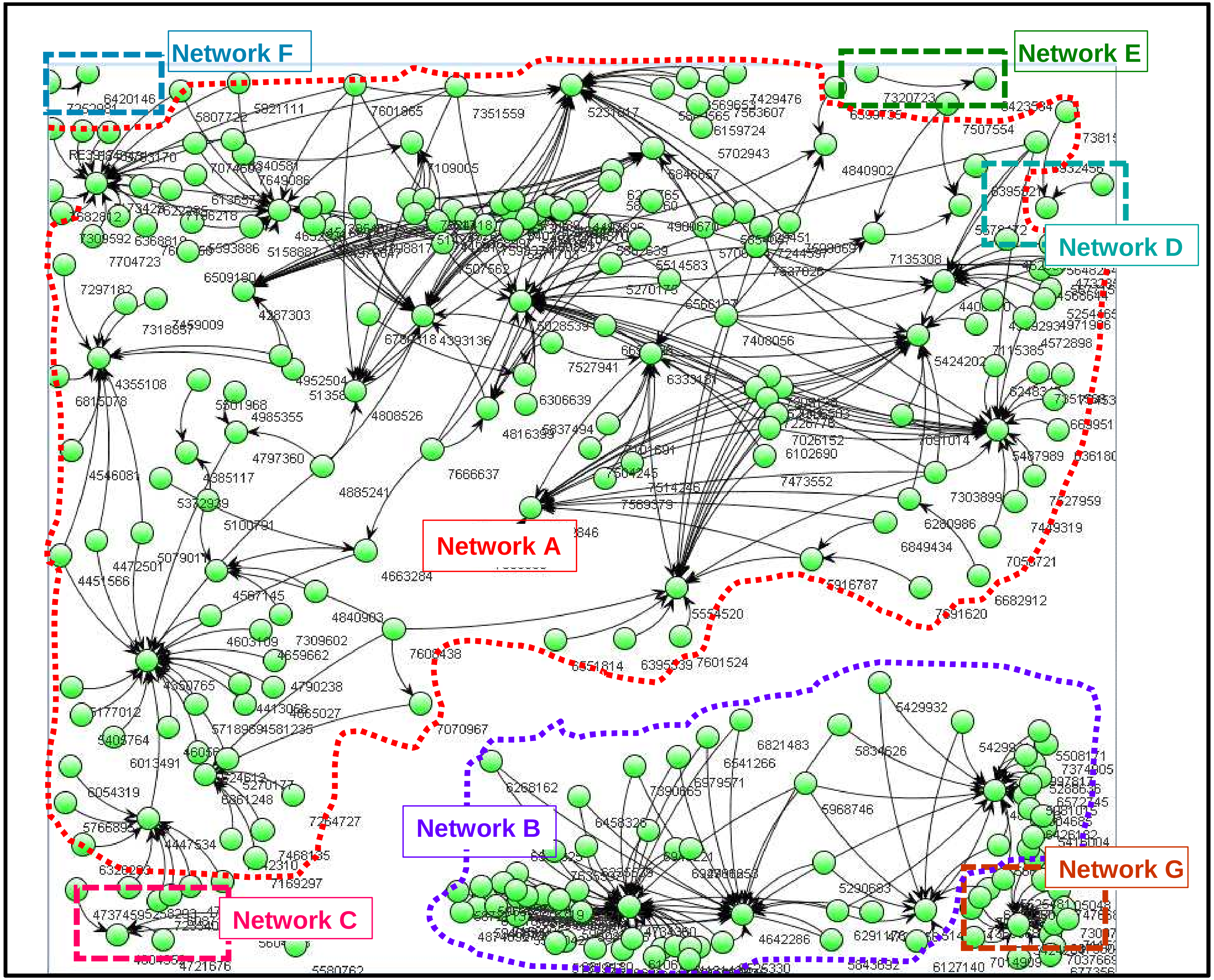


Figure 1 – Ethanol or Bioethanol network of citations – patents from United States Patent and Trade Office (USPTO), 1976-2010; C12N and C07h21 IPC Classes.

Chart 2 – Geodesic Distances of the network most cited patents

Patent (I), [USPTO number] and (number of citations)	I [4734360] (48)	II [5028539] (25)	III [5487989] (22)	IV [4350765] (20)	V [4810633] (20)	VI [5231017] (20)	VII [5231017] (20)	VIII [4642286] (18)	IX [4393136] (17)	X [5554520] (17)	XI [5424202] (16)	XII 5424204 (15)	XIII 4400470 (13)	XIV 4652526 (13)	XV 4287303 (12)	XVI [5482846] (12)
I [734360] (48)	-	∞	∞	∞	∞/2	∞	∞	1/1	∞	∞	∞	∞	∞	∞	∞	∞
II [5028539] (25)	∞	-	∞/2	∞/3	∞	∞/2	∞/2	∞	∞/3	∞/2	∞/2	∞	∞/2	∞/2	∞/4	∞/2
III [5487989] (22)	∞	∞/2	-	∞/5	∞	∞/4	∞/4	∞	∞/3	∞/2	∞/2	∞	∞/2	∞/4	∞/5	∞/2
IV [4350765] (20)	∞	∞/3	∞/5	-	∞	∞/4	∞/4	∞	∞/2	∞/5	∞/5	∞	∞/5	∞/4	∞/4	∞/5
V [4810633] (20)	∞/2	∞	∞	∞	-	∞	∞	1/1	∞	∞	∞	∞	∞	∞	∞	∞
VI [5231017] (20)	∞	∞/2	∞/4	∞/4	∞	-	∞/2	∞	∞/2	∞/4	∞/4	∞	∞/5	∞/2	∞/2	∞/4
VII [5231017] (20)	∞	∞/2	∞/4	∞/4	∞	∞	-	∞	∞/3	∞/4	∞/4	∞	∞/4	1/1	∞/4	∞/4
VIII [4642286] (18)	∞/1	∞	∞	∞	∞/1	∞	∞	-	∞	∞	∞	∞	∞	∞	∞	∞
IX [4393136] (17)	∞	∞/3	∞/3	∞/2	∞	∞/2	∞/3	∞	-	∞/3	∞/3	∞	∞/3	∞/3	∞/2	∞/3
X [5554520] (17)	∞	∞/2	∞/2	∞/5	∞	∞/4	∞/4	∞	∞/3	-	∞/2	∞	∞/2	∞/4	∞/5	∞/2
XI [5424202] (16)	∞	∞/2	∞/2	∞/5	∞	∞/4	∞/4	∞	∞/3	∞/2	-	∞	∞/2	∞/4	∞/5	∞/2
XII 5424204 (15)	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
XIII 4400470 (13)	∞	∞/2	∞/2	∞/5	∞	∞/5	∞/4	∞	∞/3	∞/2	∞/2	∞	-	∞/4	∞/5	∞/4
XIV 4287303 (12)	∞	∞/2	∞/4	∞/4	∞	∞/2	∞/1	∞	∞/3	∞/4	∞/4	∞	∞/4	-	∞/4	∞/4
XV [4652526] (13)	∞	∞/4	∞/5	∞/4	∞	∞/2	∞/4	∞	∞/2	∞/5	∞/5	∞	∞/5	∞/4	-	∞/5
XVI [5482846] (12)	∞	∞/2	∞/2	∞/5	∞	∞/4	∞/4	∞	∞/3	∞/2	∞/2	∞	∞/4	∞/4	∞/5	-

Table 3 - Subnetwork A biotechnological trajectory analysis.

Highly cited patents (USPTO nº/year)	Highly cited patents cluster technological profile	BIOEN technological areas (according to Table 1)	Raw material source of ethanol	BIOEN R&D A - Biomass Research B - Ethanol Industrial Technologies and Processing Research C-Alcoholchemistry and Biorefineries
5,028,539/ 1991	Simultaneous saccharification and fermentation (SSF), anaerobic microorganisms for non-saccharified biomass use; biorefineries technologies.	Enzymes OGM (bacteria)	Starch Sugar Non-saccharified biomass	A, B, C
5,487,989/ 1996	Metods of treatment of biomass; texturized cellulosic or lignocellulosic materials and compositions, heterologous granular starch production from genetically modified organisms; endoglucanases expression.	Enzymes OGM (fungus) Microorganisms gene expression	Starch Sugar Non-saccharified biomass	A, B, C
4,350,765/ 1982	Biomass full fermentations and metabolite control: immobilized cell reactors, design for inhibitory impacts of full-biomass fermentation; Zymomonas cultured in yeast-conditioned media; biocatalyst immobilized fungus processes biosensors for water-dispersible, gel-forming.	Enzymes OGM (bacteria)	Starch Sugar Non-saccharified biomass	A, B, C
5,231,017/ 1997	Combination of biochemical and synthetic conversions of full biomass; liquefaction step;decreasing residual starch production control.	Enzymes OGM (bacteria)	Non-saccharified biomass	A, B, C
5,173,429/ 1992	Biorefineries solvents for extraction of acetic acid from aqueous streams; biogas production from fermenting organic materials; water-immiscible solvent useful in the extraction of acetic acid from aqueous streams from anaerobic microorganisms.	Enzymes OGM (bacteria)	General organic material (wood, domestic waste)	A, B, C
4,393,136/ 1983	Biogas production from fermenting organic materials; Biocatalysts from anaerobic microbial cells for organic material fermentation.	Enzymes OGM (bacteria)	General organic material (wood, domestic waste)	A, B, C
5,554,520/ 1996	Biofefineries and ethanol production: simultaneous saccharification and fermentation (SSF);alcohol dehydrogenase genes for cellulosic or lignocellulosic materials fermentation;acid-stable alpha amylases from novel OGM fungus.	Enzymes OGM (fungus) Microorganisms gene expression	Starch Sugar Non-saccharified biomass	A, B, C
5,424,202/ 1995	Starch hydrolyzing plasmids and enzymes: Trichoderma pyruvate decarboxylase, alcohol dehydrogenases, Klebsiella phospho-	Enzymes OGM (bacteria) Microorganisms gene expression	Starch Non-saccharified biomass	A, B, C

	.beta.-glucosidase and Klebsiella (phosphoenolpyruvate-dependent phosphotransferase systems.			
6,333,181/ 2001	Ultra-sonic processes to prepare fibrous materials for microorganisms enzymes; bioreactors for baiting and growing microorganisms	Enzymes OGM (bactéria and fungus)	Starch Sugar Non-saccharified biomass	A, B, C
4,652,526/ 1987	Combination of biochemical and synthetic conversions;oil refining, carbon black, coke, ammonia, and methanol production; converting waste gases from industrial processes; high yield ethanol production with concurrent production of high value coproducts; acetic acid intermediate followed by conversion into ethanol using esterification and hydrogenation reactions.	Enzymes OGM (bacteria) Microorganisms gene expression	General organic material (wood, domestic waste)	A, B, C
4,400,470/ 1986	Thermophilic cellulose decomposing bacterias; microorganisms culturing production of the soluble enzymes.	Enzymes OGM (bacteria) Microorganisms gene expression	Non-saccharified biomass	A, B, C
4,287,303/ 1981	Industrial facilities method for sterilizing process fermentation vessels; vacuum filtering and mechanically squeezing process; hidrolysed corn starch fermentaton filters	Enzymes	Non-saccharified biomass	A, B, C
5,482,846/1 986	OGM bacteria for starch hydrolyzing enzymes; recombinant host cells containing one or more genes encoding endoglucanses which are capable of the synergistic degradation of oligosaccharides	Enzymes OGM (bacteria) Microorganisms gene expression	Starch Sugar Non-saccharified biomass	A, B, C
4,355,108/ 1982	Electrostatic precipitator and other industrial processes for biomass enzimatic processes improvements.	Enzymes	Starch Sugar Non-saccharified biomass	A, B, C
4,447,534/ 1982	Biomass hidrolysis and fermentation adsorption-desorption process using ion exchange resins;cells in a culture medium.	OGM (bacteria)	Starch Sugar Non-saccharified biomass	A, B, C
4,808,526/ 1983	combination of biochemical and synthetic conversions for biorefineries and ethanol production from anaerobic microrganisms.	Enzymes OGM (bacteria) Microorganisms gene expression	Starch Sugar Non-saccharified biomass	A, B, C
4,812,410/ 1989	Acid treatment stages at high temperature and high pressure; xylose and arabinose microrganisms fermentation for biorefineries and full-biomass materials.	Enzymes OGM (bacteria) Microorganisms gene expression	Starch Sugar Non-saccharified biomass	A, B, C
6,846,657/ 2005	Decarboxylation by an electrochemical process;raw cellulose stream by mixing a waste cellulose feed and an	Enzymes OGM (bactéria	General organic material (wood,	A, B, C

	algae cellulose feed.	**and algae) Microorganisms gene expression**	**domestic waste)**	
6,861,248/ 2005	**Acid treatment stages at high temperature and high pressure; glucose, xylose and arabinose microrganisms fermentation for biorefineries and full- biomass materials.**	**Enzymes OGM (bacteria) Microorganisms gene expression**	**Starch Sugar Non-saccharified biomass**	**A, B, C**
4,816,399/ 1989	**Microorganisms which normally do not ferment pentose sugars which are genetically altered to ferment the pentose sugars**	**Enzymes OGM (bacteria) Microorganisms gene expression**	**Starch Sugar Non-saccharified biomass**	**A, B, C**
7,109,005/ 2006	**Enzymatic simultaneous saccharification and fermentation of biomass to ethanol (SSF processes);counter-current continuous flow of an aqueous ethanol solution at elevated temperature and pressure to provide plant material depleted of lignin.**	**Enzymes OGM (bacteria) Microorganisms gene expression**	**Starch Sugar Non-saccharified biomass**	**A, B, C**
4,567,145/ 1986	**Vacuum process and selectively permeable membranes to increase ethanol production efficiency; pentosis fermentation**	**Enzymes OGM (bacteria) Microorganisms gene expression**	**Starch Sugar Non-saccharified biomass**	**A, B, C**
6,102,690/ 2000	**Bioreactor- environment conductive to the breakdown of organic aqueous material and the production of hydrogen from microorganisms; restrictive to the production of methane from methanogens.**	**Enzymes OGM (bacteria) Microorganisms gene expression**	**Starch Sugar Non-saccharified biomass**	**A, B, C**

The following considerations are relevant with respect to the “ethanol/bioethanol” network A analyzed above.

a) The R&D as revealed by the analysis of the network is directed towards the use of biomass from corn (starch). However it can easily be adapted for the use of sugarcane biomass.

b) The areas of enzyme R&D, particularly those that include simultaneous saccharification and fermentation, are based on GM microorganisms (fungus and bacteria) that can signify barriers to the R&D of BIOEN as such technologies are assignees.

c) The scenario does not involve R&D on plants, particularly sugarcane, which should be involved given that the technologies analyzed by sub-network A are applicable to the production of corn ethanol, based on starch fermentation.

d) All of the relevant technologies are important, both for the production of combustible ethanol, and biorefinaries.

Finally, special attention must be given to the patent citers of the clusters of 85% of the patents highly cited, and that are relatively recent, covering the years 2005 to 2010. They are presented in the following Table 4. Such technologies pertain to a selected group of biotechnology companies, 81% of them being North-American and 19% from Nordic countries (Finland and Denmark).

Table 4 - Recent technologies – combustible ethanol and biorefinaries”

Country	Enterprise	BIOEN R&D relationships: A - Biomass Research B - Ethanol Industrial Technologies and Processing Research C - Alcoholchemistry and Biorefineries
USA	a) ZeaChem, Inc. b) Xyleco, Inc.	B C
USA	a) Celanese International Corporation b) Bioengineering Resources, Inc. c) Genencor International, Inc.	A C
Finland	a) Cultor, Ltd. b) Valtion Teknillinen TutkimuskeskusOy Aiko AB	A, B, C
Denmark	a)Hoechst Aktiengesellschaft	A, B, C

Contributions and implications

This paper has contributed in recognizing the technological opportunities, and formulating problems that result in innovations, via what are known as “focusing devices” (Marengo e Dosi, 2000). These are defined on the basis of a systematic application of technical and scientific knowledge by agents who compete in a context of selective market processes.

These processes take different trajectories and generate different patterns of technology diffusion within firms, between firms, among firms in the same industry, and between industries and sectors.

From a macro structural analytical approach, it is possible to conclude that the “ethanol from the sugar cane R&D process” is an emergent technological enterprise. However, dual technologies, already present in the innovation networks presented in this study, show that it is necessary to understand, from a business point of view, how such assignee capacity can impact the R&D of sugarcane biotechnology.

From BIOEN’s micro-aspects of technological capacity building, other broader considerations about the innovation dynamics and about the holes of the different clusters, hubs and connectors will most likely be found.

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