Innovation Forum VI - 2014
Crisis, innovation and transition
1, 2 and 3 October 2014 (University of Paris Ouest, Nanterre, La Défense)

Innovation strategies diversity in the biobased economy: a comparative approach

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The development of a renewable based industry should be seen as part of a larger movement which is designed as bioeconomy or biobased industry (OECD, 2009; White House, 2012). This industry is under construction and its structural dimensions are not yet defined. The competition is so oriented by innovation strategies in an environment with high level of uncertainty.

Some key drivers are pushing the biobased industry: the *white biotech* or industrial biotechnology potential, the fossil use restrictions, the strategic orientation of some key firms and the perspective of technological innovation as a crisis exit.

Biomass as feedstock is still used principally in biofuels production. But, while biofuels are expected to grow at around 10% cagr, growth rates for bioproducts as chemicals and materials (bioplastics and biopolymers) are estimated at higher than 20% cagr. This expressive growth in bioproducts highlights the diversity in the biobased industry.

The biobased industry should be analysed as an emergent industry (Bomtempo, 2013). Some key dimensions mark this condition: the high number of innovating projects with very different and competing solutions trying to seize the market opportunities; the emergence of a notable number of startups supported by grants and innovation policies and by expressive resources from venture capitalists; the emergence of an extensive new knowledge basis, in particular the synthetic biology; the strategic entering movements of established firms from different industries; and last but not least important the process of feedstock changing – from oil and gas to biomass sources – which historically has been driving structural changes in the industry.

Competition in the biobased industry is so based on innovation and strategies aim at shaping the industry structure. Considering an emerging industry, the selecting environment is complex and competitive patterns are not established yet. Product and process innovation occur intensely, without the existence of dominant designs or enabling technologies. Entry and exit barriers are low, with co-existence of innovators from different knowledge background proposing several concepts, building diverse technological trajectories. This structuring process can be understood as the outcome of the co-evolution of four dimensions: feedstock supply, treatment and conversion technologies, products and strategies (Bomtempo and Alves, 2014).

This paper explores profiles of firms involved in the biobased economy construction. It identifies the key elements of their innovation strategies and explores the nature of diversity innovation strategies at the industry and firm level.

Theoretical background

Innovation strategies, particularly in emergent industries such as the biobased industry should be studied in a competence/resource based view in order to spot actors' strategic movements aiming at shaping the industry and establishing first mover positions. Dynamic capabilities (Teece, Pisano, Shuen, 1997; Teece, 2007) are critical in this kind of environment for incumbents and start-ups firms as long as they have to interpret signals from multiple levels. Taking the Geels's approach (Geels, 2004), transition from fossil based industry to renewable based one involves landscape, regime and niche developments. Actors, in our case innovating firms, have to interpret and deal with these different and complex signals. In this dynamic environment, resources and competences are unequally distributed among the firms. Thus, the capacity to identify which competences are central or core competences (Hamel and Prahalad, 1990) and which competences are complementary and must be accessed from other sources (and how to access them) is very critical for the innovation strategies.

Hamilton (1990), studying the biotechnology industry in the 1980s, proposes analytical frameworks and categories which can be brought to discuss the current bioeconomy scenario. Hamilton (1990) stresses that the emergence of a new industry involves not only technological breakthroughs, but also the development of a new industrial structure. Consequently, the competition requires new strategic approaches. Hamilton (1990) proposes a framework that relates the strategic options with technology evolution, organizations and their position after a technological breakthrough, differentiating established firms and start-ups. Considering the innovation dynamics model (Abernathy and Utterback, 1978), the analysis focuses on the fluid phase, where the uncertainties and risks are caused by the absence of a dominant design. Hamilton

(1990) presents a general pattern of technological development at this stage, linking innovation efforts in three phases with distinctive emphasis on science, technology and marketing, respectively. This pattern guides the evolution of the participants, their strategies and business models. According to Hamilton, established firms faced to a new industry could enforce three basic strategies: window opening, creating options and establishing positions. At the same time, emerging firms or technology based start-ups try to follow a different road: creating business, expanding options and also establishing positions.

Hamilton's approach allows a very useful understanding of innovation strategies. However, as long as in the biobased industry firms profiles are more diversified and incumbent role is not clearly defined, Hamilton's framework remains at a general approach of innovation strategies, lacking, in our perspective, a discussion on specific aspects at firm level. We propose to refine the understanding of firm strategies in the biobased industry taking into account the Teece's framework (Teece, 2007) which tries to identify the microfoundations of enterprise performance in the dynamic capabilities perspective. Concerning the microfoundations of firm performance in fast-moving and unstructured environments, Teece (2007) proposes to disaggregated the dynamic capabilities into three particular capacities: to sense and shape opportunities and threats, to seize opportunities and to maintain competitiveness through organizational process that protect and, if necessary, reconfigure firm's assets. Sensing and shaping opportunities and threats are conducted by processes that allow the firm to understand the environment and define its goals. Seizing is related to the way firms structure their business models in order to create and appropriate value. Learning and adapting processes are at the center of the management of threats and organizational reconfiguration enabling adjustments.

This work focuses on sensing/shaping outcomes and seizing strategies as a way to identify and characterize the diversity of innovation strategies in the emergent biobased industry. We explore four aspects of the innovation strategies related to the diversity in the biobased industry: distributed competencies according to the origin industry, the firm commitment to the bioeconomy, the sensing/shaping outcomes and the seizing strategies.

Methodology

This study is based on multiple case studies exploring the innovation strategies of the most known enterprises in the biobased landscape. It draws on findings from a research program on the technology and innovation dynamics in the bioeconomy, particularly in the biobased industry, developed in the last four years by the authors. A proprietary data base was organized from public information available from the specialized press (for example biofuelsdigest.com publishes a free access data base which address valuable information on projects and enterprises; blogs such as www.greenchemicalsblog.com cover almost every movement in the industry), professional conferences, special reports (for example from OECD, IEA task 42, DOE and others), companies' reports, in particular 10k forms. Using the data base, it is possible to describe companies' trajectories and their innovation strategies in the biobased industry. We had also access to Braskem[1]'s database and roadmap on renewable chemicals to which we express our thankfulness. In order to compare firm profiles and explore strategy diversity dimensions such as entering motivation, partnerships, product portfolio and business models will be considered.

[1] Braskem is one of the largest chemical and petrochemical companies which has been showing interest in investing in biobased products.

Discussion and results

Distributed competences

Business models and strategies are well known for first generation ethanol and biodiesel. But, considering innovative biofuels and biobased chemicals, the industry is still under construction. In the structuring spaces we have identified – feedstocks, technologies, products and business models – a very diverse group of firms is in competition. These firms can be grouped as presented in table 1. We can identify technology based startups such as Genomatica, Solazyme, LanzaTech, Gevo, Amyris, Renmatix, Kior and many others; firms from the chemical and petrochemical industries such as DuPont, DSM, BASF, Braskem, Dow, Solvay; oil and gas companies such as Shell, BP, Petrobras, Total, Neste; agribusiness companies such as ADM, Bunge, Cargill; food ingredients companies such as Tate&Lily, Roquette, Purac; pulp and paper firms such as Stora Enso, UPM, Borregaard, Fibria, not to mention venture capital investors (Bomtempo, 2013).

These different firm profiles imply different key-competences with which companies try to enter the biobased industry. At the same time, there are complementary competences which each firm has to access to achieve a competitive position in the industry. As a consequence, different business models have been tested. These different business models reflect the different ways to value the firm's key competences and to associate in order to acquire the complementary competences. Thus, even if the most innovative technologies have emerged from the technology-based startups, much of the complementary requirements - feedstock supply, scaling-up and production at commercial scale, marketing and commercialization – are held by established companies. These companies - eg the chemical and petrochemical companies - have

expertise and complementary assets needed to establish relations with the user industries (end users) and develop commercial applications. Table 1 synthesizes industry profiles and their key competences and also the commitment to the industry evolution. The latter point is discussed in the next section.

	STARTUP	**CHEMICAL PETROCHEMICAL**	**AGRI BUSINESS**	**FOOD INGREDIENTS**	**OIL & GAS**	**PULP AND PASTE**
Key Competences	Technology	Production; commercialization	Access to feedstock; logistics	Biomass processing	Production; fuel commercialization	Access to feedstock; biomass pre-treatment
Complementary Competences	Access to feedstock; Production; commercialization	Access to feedstock; technology; advanced biotech	technology; production; commercialization	technology; production; commercialization	Access to feedstock; technology; advanced biotech	Technology, commercialization
Bioeconomy Importance to the firm	Extremely high	Depends on the firm strategic vision	Depends on the firm strategic vision	Average	Average	average
Firm Importance to the bioeconomy	Very low for an isolated firm; very high for startups	High	High	Average	Average	average

Table 1 – Firm profiles and competences related to the bioeconomy

Commitment to the industry evolution

In this section and in the rest of the paper, we emphasize startup companies, chemical and petrochemical, and oil & gas industries. Table 1 includes a discussion that is not frequent in the research on emergent industries: the relative importance that firms consider in their strategies to their participation in the industry. The other side of the coin which seems relevant to take into account is the importance of firm for the development of the industry. These reciprocal relationships can be critical to the development of cooperation and alliances among firms and to the understanding of their efforts in the industry. Startups are strongly involved in the industry for the simple reason that if the industry fails to emerge they don't have any issue. In the bioeconomy, chemical and petrochemical companies commitment depends largely on each particular strategic vision. Du Pont and DSM are notable cases of commitment to the bioeconomy. Strategic decisions have been made to support a transition path from a traditional chemical company to a biotechnology-based pioneer in bioeconomy. Other chemical

and petrochemical companies show a more defensive strategy aiming at preserving their positions in the established industry. Although Braskem commitment to bioeconomy is becoming stronger (more involvement in R&D, two associations with startups – Genomatica and Amyris – to develop new biobased products), this involvement is still in drop in[2] products for which Braskem already has presented an established industrial and commercial know-how. Dow commitment to the bioeconomy has weakened with the decision to postpone bioplastics projects in Brazil and invest its resources in shale gas feedstock in USA. Oil & gas companies are at a first view less committed to the bioeconomy. As a rule, focus is on biofuels preserving their traditional markets. Preserved But even in this specific market, involvement can be explicit and high – Shell, BP and Petrobras, for example – and minimal – Exxon for example. The degree of commitment has implications to the alliances and to the emergence of the biobased industry itself. As long as bioeconomy is not strategic for a chemical, petrochemical or oil company, their decisions are easily reverted. Some startups have experienced difficult situations when apparently well conceived alliances are unexpectedly broken as a result of changing vision of the partner. One good example which illustrates this point can be the end of partnership between ADM, the giant of agriculture and food producer, and Metabolix, a technology based startup oriented to develop and commercialize a non drop in bioplastic. After ADM ending the alliance, Metabolix had to stop its accelerated growth and downsized its organizational structure revising target market from a broad approach to specific niches.

Nevertheless, even if the commitment of companies from the established industries is variable and unreliable, their resources and competences availability is extremely important to the bioeconomy as an emergent industry. Oil & gas companies, for

[2] Drop in biofuels or bioproducts refer to the condition of being identical or enough similar to the fossil-based product. In this case the complementary assets are preserved and the diffusion of the new biofuel or bioproduct depends only on its cost.

example, invest in biofuels industry modest amounts compared to the investments in their core business. But these investments, from Shell, BP and others, are expressive to the bioeconomy environment. Even Exxon, a remarkable example of a non committed company, has invested an expressive amount (an initial investment of US$ 300 million in 2009) in Synthetic Genomics, a highly innovative startup in advanced biofuels from algae.

Sensing and shaping outcomes

Studying the revealed outcomes of sensing processes conducted by firms involved in the bioeconomy allows a more nuanced view of dynamic capabilities building and the firm innovation strategy. The exploration of sensing processes also permits to explain the diversity in firms strategies even from the same origin industry and observe the difference in addressing opportunities through structuring process explored by seizing capabilities discussed in the next section.

Most of startups which are in average 10 years old have innitially identified biofuels as the opportunity to be shaped (Amyris, Solazyme, Enerkem, Coskata, for example). But while ethanol was the focus of Enerkem and Coskata, non-ethanol drop in biofuels was the market opportunity identified by Amyris and Solazyme. Currently, Enerkem and Coskata still focus on ethanol, while Amyris and Solazyme with a synthetic biology platform are exploring opportunities in bioproducts (Solazyme) and in biofuels and bioproducts (Amyris).

Braskem initially identified opportunities in drop in bioplastics and successfully developed a “green” polyethylene from ethanol by a conventional chemical technology. But Braskem has identified opportunities in synthetic biology based routes and recently

tied up R&D projects with Amyris and Genomatica to develop drop in bioversions of petrochemicals. A somewhat contrasting trajectory was followed by Shell. About 10 years ago Shell had a very open vision of opportunities in biofuels with focus on advanced biofuels like second-generation (waste-based) ethanol, biogasoline, biomass-to-liquids biofuels and algae. Trying to shape these opportunities Shell followed an option creating strategy (according to Hamilton's typology, Hamilton, 1990) and invested in five different startups. But in the last 5 years this perception of the opportunities in biofuels were extensively changed. Shell abandoned three of the five participations and founded a joint venture with the biggest Brazilian ethanol producer, Cosan. Shell reversed its perception of the opportunities in the bioeconomy to a narrower vision with focus on ethanol, first and second generation.

Sensing processes at Du Pont were apparently much more elaborated. In the end of the nineties, Du Pont decided to start a profound change in its technological base incorporating biotechnology and renewable feedstock as the source of long term growth. In the last years, strategic movements such as the acquisition of Danisco, an important enzymes producer, have reinforced this transition process evidencing its sensing and seizing capabilities.

Seizing opportunities

Seizing opportunities is a critical dimension of dynamic capabilities building. According to Teece, 2007, "…*the issue that enterprise faces is not just when, where and how much to invest. The enterprise must also select or create a particular business model that defines its commercial strategy and investment priorities"*(pag). To develop a business model in the biobased industry is a quite challenging task. Apart its emergent stage, the startups and established companies from different origins face an industry where the business model has to combine solutions in three other critical dimensions:

feedstock, technologies and products. To make decisions at the three dimensions and articulate them properly is very complex as the distributed competencies (see table 1) suggest.

We describe below three cases[3] of startups – Metabolix, Amyris and Solazyme - and their dynamic capabilities building process (sensing and seizing). These cases illustrate the sensing and seizing capabilities in the bioeconomy.

Metabolix

Metabolix, a spin-off from MIT, was founded in 1992 initiating a series of investments in the development of technology for producing PHA bioplastics. PHA is obtained from fermentation process through genetically modified organisms. Since its beginning, sensing related strategic decisions where focused on this specific product. In the 1990s attention was given to issues regarding biodegradability, since environmental worries were related to plastic pollution. In 2006, strategic decisions regarding seizing the opportunity to produce and commercialize PHA started to appear. Metabolix established a joint venture with ADM, one of the largest agricultural and food production companies. The commercial plant for production of 50 ktpa of PHA came into operation in 2008. From 2006 to 2011, the organizational structure of Metabolix changed from a startup to an operational profile. The company focused its efforts on increasing the number of possible applications for its material, working in various target segments. In this period, the startup was mainly financed through resources of ADM. Just under two years after the startup of the commercial plant, ADM announced the end of the joint venture. The company lost its operating assets (the production plant), having to reduce its administration team and downsizing its structure.

[3] This part draws on Business Model Innovation and Dynamics in Emerging Industries, Alves, Bomtempo and Oroski, 2014.

The loss of the plant in Iowa has led the firm to look for a new value proposition: cut its target market to 10 ktpa, focusing on segments that value the biodegradability, such as uses in agriculture and containers for organic compounds. In addition, the company is investing in the development of PHA copolymers, used as a properties modifier additive of PVC plastic. In 2012, other important partnership was established with the chemical company Samsung Fine Chemicals in order to develop blends of PHA with other biodegradable biopolymers, which could represent a relative change in its business model. We observe than a shift in strategic decision related to sensing opportunity, but the firm maintained PHA as the centre of its decision. This approach constrains the possibilities in mobilizing seizing dynamic capabilities to restructuring the business model. Metabolix has not flexibility to experiment a variety of arrangements, since the needed complementary assets are restricted.

Amyris

Amyris is a biotechnology start-up established in 2003 to produce artemisinin, a new malaria drug. Its headquarters are in Emeryville, California, USA where the basic research activities are developed. The firm has adapted the knowledge developed in the pharmaceutical biotechnology industry to enter the biofuels sector, producing drop-in diesel. This was the first strategic decision related to sensing opportunities within the biobased industry. An innovative process of fermentation was developed using synthetic biology to modify yeasts to produce hydrocarbon molecules from sugars. Farnesene was the chosen molecule to work as a chemical platform, since this would enable diesel production.

As the firm started mobilizing seizing dynamic capabilities in order to structure its business model, it selected Brazil to place its commercial facility, where it could get

competitive raw material (sugarcane). It was possible to notice a change in Amyris sensing related strategic decision once it announced interest in exploring other markets than biofuels. It remained with farnesene as the basic molecule but expanded target markets, since farnesene can find several applications, depending on specific chemical finishing: elastomers, lubricants, cosmetics products, aviation fuel, fragrances, etc. This shift was followed by the establishment of many partnerships in different modes (joint ventures, development agreement, production contract) and with a wide diversity of partners, which shows a room for experimentation and feedback in business model innovation. In an attempt to expand the opportunities for innovation and get complementary assets and lacking competencies, Amyris sensing and seizing capabilities have been mobilized to evolve business model. Many different forms have been used for structuring scale production and relationships with customer segments.

Solazyme

Solazyme is a biotechnology start-up founded in 2003, headquartered at California, USA, where the research activities are developed. The company pioneered an industrial biotechnology platform that enables transforming low-cost plant-based sugars into high-value oil using microalgae as a biocatalyst. Although a diverse portfolio of products can be achieved through its process, the company initially focused on biofuels, but broadened it rapidly to three target markets: chemicals and fuels, nutrition and skin and personal care. Solazyme oils are said to be drop-in replacements, compatible with existing production, refining and distribution infrastructure in the target markets. Since 2007, Solazyme have operated in commercial-sized standard industrial fermentation equipment through manufacturing partners. In 2011, the company purchased a facility in Peoria, Illinois, where commercial production of alguronic acid, used in skin and

personal care ingredients, began in 2012. In what concerns chemicals and fuels, the company formed a joint venture with Bunge, one of the largest sugarcane processing companies in Brazil and started commercial scale production this year, in a facility co-located at one of its sugarcane mills.

Some lessons can be drawn from three startup cases explored: (1) Sensing depends on a clear understanding of the environment in an industry under construction. A clear perception of opportunities to be explored by firm can lead to different seizing strategies determining which target markets will be prioritized. (2) Sensing decisions on technological platform instead of product view may allow a wide range of possibilities which expand the opportunities for innovating firms. In some cases, firms have to develop different business models for different market segments. (3) Seizing capability more related to the structuring process should consider four dimensions (feedstocks, technologies, products and business models) and integrate them since they are strongly interrelated representing a major challenge for firms. Some arrangements can emphasize one or two aspects neglecting others and causing an imbalance. Decisions concerning feedstocks can lead the firm to establish an alliance with a specific partner that can influence in decisions about specific products and business models narrowing sensing opportunities. (4) Commitment aspects should be investigated by innovative firms when establishing partnerships. The role of complementary competences is easily understood by innovators but the comprehension of partners commitment is critical to define and drive their future decisions as persisting or abandoning the project.

Conclusions and implications.

Different firms with different profiles have been trying to enter the biobased industry. These firms have different key competences related to the biobased industry. On the

other hand, they need to add different complementary competencies in order to compete in the industry. This situation reflects the stage under construction, unstructured, of the biobased economy. An implication is the crucial importance of alliances and associations in the innovation strategies.

The fact that different profiles have different importance to and for the bioeconomy has some interesting implications. Larger firms from established industries such as oil and gas, chemical/petrochemical and agri-business may have a relatively short-term view, be impatient or unsatisfied with the first results and abandon the projects. Nevertheless, firms from the same sector can have different behaviors. The decision to keep or to abandon a project depends also on their global financial performance and on the entering motivation.

Even if some firms have been adopting a relative conservative position in this emerging industry, some examples of established firms illustrate how they can open their sensing to explore new technological basis and market opportunities and promote significant changes in their business strategies. Since these actors, startups and established firms, are in a fast moving environment, it seems to be crucial to develop sensing and seizing capabilities to face uncertainties and promote adjustments to the biobased industry.

Concerning strategy diversity, our initial analysis, based on the sensing and seizing capabilities building, tends to reinforce the idea that this diversity is driven firm specific factors with a minor influence of industry factors. This point deserves to be studied more deeply in the ongoing research.

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