Title

Exploring business model dynamics in fast-changing environments: the case of the bioeconomy

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Abstract

The bioeconomy is a complex selection environment where competitive patterns are not yet defined. The shift from a fossil based to a biobased economy encompasses significant challenges for the firms interested in participating in the production of bioproducts. Among these firms, startups are especially subjected to difficulties, due to their limited resources, the necessity of constantly adapt to the opportunities and threats of this emerging field, the large investments required to advance new technologies and the variety of possible partners from different sectors. To grow and achieve economical sustainability, start-ups need to both advance new technologies and experiment with business models (BM). Bioeconomy is an interesting setting for analyzing these underlying dynamics. Exploring how startups BM are evolving is relevant to understand both the bioeconomy and the paths followed by these firms. Despite this, the theme is not frequently explored in the related literature.

Our aim is to identify factors guiding BM decisions, its degree of flexibility and how firms are mobilizing sensing and seizing dynamic capabilities to build their BM. Our research relies on multiple case studies structured from secondary data sources of six startups with different profiles and in large evidence within the bioeconomy: Amyris, Avantium, BioAmber, Genomatica, Metabolix and Solazyme. We dialogue with the literature on dynamic capabilities, since it provides a useful framework to understand firms' responses to fast-changing environments, including new business models design.

We found that firm's technological possibilities and the product nature (drop-in or non-drop-in) affect the flexibility in BM experimentation, while the assumed firm profile (producing or licensing) stands as an important decision that must be weighted by existing constrains of the industry. We draw from our results a new decision flow chart that gives a concise view on how to sequentially consider these factors when designing a business model.

1. Introduction

Emerging industries constitute a complex selection environment where competitive patterns are not yet defined. The bioeconomy (or bio-based economy) fits in such definition (OECD, 2018). It is a recent, on-going phenomenon that emerged as a response to concerns on scarcity of resources, increasing population and environmental impacts characteristics of our current fossil-based economy. The bioeconomy involves a variety of emerging fields in which renewable feedstocks and/or biological sciences can play a decisive role as drivers of innovations, hence allowing the involvement of different established industrial sectors, such as agribusiness, chemicals/petrochemicals, food and feed, oil and gas, paper and pulp, and others, besides technology-based start-ups (Bomtempo and Alves, 2014; Bomtempo et al., 2014). This aspect of novelty and the complexity of the bioeconomy demand advancing various research topics, especially those related to innovation. It includes, for example, designing sustainable business models (e.g. (Iles and Martin, 2013; Nair and Paulose, 2014)), addressing technology and innovation management (e.g. (Golembiewski et al., 2015; Van Lancker et al., 2016)), the comprehension of the bioeconomy innovation dynamics (e.g.Bomtempo and Alves, 2014)), to name a few. However, analyses of business models (BM) dynamics in this fast-changing environment are still missing.

In order to grow and achieve economical sustainability, start-ups need to simultaneously surpass the inherent challenges of further advancing embryonic technologies and experiment in BM design. The bioeconomy is an interesting setting for analyzing BM innovation and dynamics, since several recently founded technology-based firms are able to participate in its construction. Our aim is to identify key dimensions that guide BM decisions, how firms are mobilizing sensing and seizing dynamic capabilities (Teece, 2007) to build their BM and the degree of flexibility achievable in the context of the bioeconomy. Understanding such factors is relevant from a practical perspective, since may aid start-ups decision-making processes, as well as from a theoretical perspective, by discussing the emerging dynamics capabilities constructs along with business models experimentation (Teece, 2018).

Firms in emerging industries need to find the most adequate strategic approaches regarding product/market positioning, marketing, servicing, as well as, product configurations and production technologies (Porter, 1980), in a selection environment where competitive patterns are not yet defined and technological innovation is still in a fluid phase (Abernathy and Utterback, 1978). The biobased industry involves such difficulties, but the coexistence of innovators from different knowledge backgrounds proposing multiple concepts and constructing diverse technological trajectories, besides the fact that the assets required to commercialize such innovations are hold by different players (Bomtempo et al., 2014) expands the challenge of designing business models.

Chemical and petrochemical, oil and gas, agribusiness, food ingredients and pulp and paper firms are some of these innovators, in addition to technology-based startups that generally propose the most radical innovations. These are emerging new firms founded to advance specific innovative technologies and have a relevant role in emerging industries, due to both their innovation capabilities and low organizational rigidities, which allow more flexibility in business models experimentation in comparison with established firms. Startups involved with the biobased industry are especially subjected to difficulties in designing business models, due to the necessity of constantly adapt to the opportunities and threats of this emerging environment, the usually large investments required to advance technologies, the variety of possible partners originated from different sectors and their influence on startup trajectories.

Alves et al. (2014) highlight that different strategic focuses impact startups' flexibility in BM design. The focuses identified by the authors are: (1) exploration and manipulation of technologies to yield different products, (2) exploration of the potentials of platform chemicals and (3) exploration of the potentials of final products. Although identifying such relationship between strategic focus and flexibility constitutes a valuable insight, the authors' analysis is rather preliminary and lacks a deeper exploration of other factors that may affect business BM design. In this paper, we address these issues, analyzing technology-based startups that engage in biobased products directly affecting the chemical and petrochemical industries (e.g. biofuels, bioplastics and biochemicals). Besides identifying factors impacting BM experimentation and flexibility, we draw from our results a new decision flow chart that gives a concise view of how to sequentially consider startups' technological possibilities and how they may be constrained by business model choices.

The remainder of this paper is structured as follows. We first present both the empirical setting and research methods. Then, we present the theoretical concepts required to support our analyses. In the following section, we present our empirical findings and discussions. We conclude by outlining our contributions and additional research themes that scholars can pursue in the future, related to the context of emerging industries and the bioeconomy.

2. Research approach

Alves et al. (2014) do set an interesting starting point for the present paper, distinguishing three strategic focuses: exploration and manipulation of technologies to yield different products, exploration of the potentials of a platform chemical and exploration of the potentials of final products. In the first case, exploration and manipulation of technologies, the main feature of the startup is not a specific set of products, but its ability to provide different solutions according to market or customers' demands. Platform chemicals may be defined as chemical intermediates capable of yielding a large set of derivatives through specific physical and chemical transformations, targeting several distinct end-uses (Bomtempo et al., 2017). Bozell and Petersen (2010) list some biobased products that exhibit potential as platform chemicals, all of them not yet intensely explored on a commercial scale (such as succinic acid or levulinic acid, for example). Another strategic focus devised is the exploration of final products potential. For the purposes of this study, we define final products as a chemical or a mixture of chemicals that will not be subjected to further chemical transformations before its end-uses, which includes, for example, resins, fuels, base oils and solvents, chemicals used in formulations and as food ingredients. Typically, these final products are in the interface with other industries, such as converters, pharmaceutical, personal care, etc., all of which detains expertise considerably different from the biobased industry.

Our research relies on longitudinal multiple case studies of firms with different profiles, namely: Amyris, Avantium, BioAmber, Genomatica, Metabolix (now Yield10) and Solazyme (then named TerraVia and recently acquired by Corbion).These firms were selected for their strategic focuses (platform chemicals, final products or technology platforms) and for figuring among the first start-ups entering the bioeconomy in the beginning of the 2000s. The case studies were structured from secondary data sources and around narratives of these companies' business trajectories since their inception, identifying claimed business strategies, products and technologies targeted, and partnerships. Data sources used included specialized press (e.g. www.biofuelsdigest.com, www.greenchemicalsblog.com and ilbioeconomista.com), special reports of governmental and international organizations (e.g. from DOE, OECD and IEA task 42), professional conferences, annual reports (e.g. 10k forms), press releases, among others. Specifically for the purposes of this study a systematic effort was conducted to gather clear and detailed information on each startup under analysis, including the companies' background, their main assets and how they access complementary assets[1], disclosed partnerships, products and markets targeted, their current business strategies, possible strategic shifts during time, etc. In table 1, the selected firms are identified according to their strategic focus and main products.

Multiple case analysis enables comparisons that clarify whether an emergent finding is merely idiosyncratic to one single case or replicated in numerous cases (Eisenhardt and Graebner, 2007). Differentiating firms by their strategic focuses also contributes for an embedded design (Yin, 2009), since it makes possible analyses between the pairs and across the six firms.

[1] Complementary assets include competitive manufacturing assets and know-how, access to distribution and marketing channels, after-sales and technical services, and complementary technologies and marketing (Teece, 1986).

Table 1 – Summary of startups selected according to their profile

Strategic focus	Company	Main products focused
Technology manipulation	Genomatica	Intermediate chemicals, notably 1,4-butanediol and butadiene
	Solazyme* (now TerraVia)	Triglyceride oils using microalgae as biocatalyst
Platform chemical	Amyris	Farnesene, its derivatives and other isoprenoids
	BioAmber	Succinic acid and its derivatives
Final product	Avantium	PEF polymer, FDCA and levulinics
	Metabolix	PHA biopolymers

3. Brief literature review

The business model concept has received increased attention within the strategy literature, but there is still a lack of clarity regarding its meaning (Zott et al., 2011). Nevertheless, Wirtz et al., 2016, identify a convergence in the business model view across the management literature. As argued by Teece (2010), we state in this paper that a business model can be understood through three main dimensions: value proposition, value chain structuring and value capture.

Our initial hypothesis is that the strategic focuses explored by the startups (table1) entail different ranges of products to be offered, which in turn may affect the firm capability to experiment in business model design. For a startup with limited resources, having a restricted set of opportunities to choose from can result on commitments to opportunities that are not economically feasible in the current stage of the industry or that are challenging to manage, consequently, leading to the startup failure. Conversely, a broader number of opportunities may allow early adaptations in business models, i.e. leading to some experimentation and flexibility. Considering that new business models are rarely successful as firstly designed (Sosna et al., 2010) and the dynamism of the bioeconomy, assessing the flexibility of startups to adapt and experiment in business model design is of paramount importance for practice. In this perspective, we aim at assessing the degree of flexibility associated with those three strategic focuses and its relationships with business model experimentation. We also explore if and how other aspects impact business model design.

Our analysis is supported by Teece's (2007) framework on dynamic capabilities and theirs microfoundations. According to Teece, 2018, business models and dynamic capabilities are interdependent: "*The strength of a firm's dynamic capabilities help shape its proficiency in business model design".* We explore in our cases this relationship between dynamic capabilities and business models.

Derived from the Resource Based View (RBV) approach, which sees resources and competencies as crucial for sustainable competitive advantage (Barney, 1991), the dynamic capabilities acknowledge that in fast-changing business environments, where the geographical and organizational sources of innovation and production are dispersed, maintaining competitive advantage demands more than the possession of difficult-to-replicate resources and competencies (Teece, 2007). It would be imperative the mobilization of unique and difficult-to-replicate dynamic capabilities, defined by Helfat et al. (2007, p. 4) as "*the capacity of an organization to purposefully create, extend, and modify its resource base"*, where the *"resource base"* includes the *"tangible, intangible, and human assets (or resources) as well as capabilities which the organization owns, controls, or has access to on a preferential basis"* (Helfat et al., 2007, p. 4).

Teece's (2007) framework distinguishes three basic dynamic capabilities: sensing and shaping opportunities and threats (environmental comprehension and goals definition), seizing opportunities (structuring) and managing threats and reconfiguring (the process of learning and readapting). Sensing and shaping new opportunities are very much a scanning, creation, learning, and interpretive activity, normally supported by investment in research and related activities. Seizing occurs after a technological or market opportunity is sensed and shaped, being addressed by investing in new products, processes, or services, and encompassing the design of a suitable business model. Finally, reconfiguring dynamic capabilities address the rigidities in resources and assets resulting from the enterprise success, which leads to unfavorable path dependencies. In face of markets and technologies changes, such dynamic capabilities allow the firm to recombine/reconfigure established assets and organizational structures, thus sustaining its competitive advantage (Teece, 2007).

Although our empirical research design does not allow the description of these firm-level processes (i.e. these dynamic capabilities), we are able to highlight startups' strategic decisions that are indicative of sensing and shaping, seizing or reconfiguring, which is useful for evaluating how flexible the companies present themselves along their business trajectories. We hope that such approach further contributes to the still underdeveloped theory concerning dynamic capabilities (Helfat and Peteraf, 2009), by focusing on the interplay between the process of business model design, and sensing, seizing and reconfiguring.

4. Empirical findings and discussions

This section presents our main findings. We start with a summary of the trajectories of the six startups analyzed (4.1). Based on these trajectories, we identify the factors impacting flexibility in business model experimentation (4.2) and we explore the dilemma "producing or licensing" (4.3) and business model possibilities (4.4) which allow us to draw a comprehensive decision flow chart. Finally, we return to the discussion of sensing/shaping and seizing dynamic capabilities on business model design exploring the lessons from the cases.

4.1 Companies overview

Genomatica

Genomatica is a biotechnology startup founded in 1998 and headquartered in San Diego, California. Since its early days, the firm has a strong commitment to using biological modeling and simulation technologies to transform the manner through which organisms are engineered and drugs are discovered. As of 2005, Genomatica was seen as a leader in biological pathways simulation, providing modeling solutions for both academic and commercial users. Its proprietary SimPheny™ modeling platform was designed to rapidly generate broad information regarding genes, proteins, and biological pathways, as well as information on the expression, regulation, and potential products that affect these biological systems. Genomatica's was seizing this opportunity much around licensing its software and providing related services, such as training and scientific support (BioSpace, 2005). The development of such modeling platform can be pointed as the first strategic decision related to sensing opportunities, but not particularly related to changes in the chemical and petrochemical industries (as is the focus of the present study).

Following many projects in advanced biofuels around the globe and highs in oil price, Genomatica decided to reincorporate and review its business model around 2007. Since then, the company has been building a vast intellectual property portfolio in basic and intermediate drop-in chemicals (identical to their oil-based counterparts but obtained from different renewable feedstocks) and decided to license the related technologies by forging strategic alliances with industry partners (Xconomy, 2012). Although the opportunity sensed was somewhat different from the previous one, the firm intended to seize it similarly, as a licensor. Even so, Genomatica needed to engage in helping build the initial plants (pilot, demonstration or commercial), which was not foreseen by the company (Xconomy, 2012). The seizing process was conducted by maintaining Genomatica as a privately held company, receiving investments from the venture capital and other partners (Genomatica, 2015).

From 2007 on, Genomatica focused its development efforts primary on BDO (1,4-butanediol, a raw material for synthetic fibers production), butadiene (mostly used in synthetic rubbers) and, recently, on nylon intermediate chemicals such as hexamethylene diamine (HMD), caprolactam and adipic acid. For the first two, the firm has already established partnerships with chemicals producers such as BASF, Novamont, Braskem and Versalis. In some instances, production of derivatives such as PBT (polybutylene terephthalate) has been conducted using BDO obtained through Genomatica's process, but with no direct participation of the firm (Biofuels Digest, 2015). In 2015, Genomatica partnered with Cargill, an agribusiness company, in an agreement through which the companies will co-market Cargill's feedstock and production services to current and prospective Genomatica licensees. Genomatica will focus on the process technology, while Cargill can provide the required feedstocks, but can also build and operate biobased chemical plants for chemical producers or consumers. Cargill offers its experience in fermentation-based processes, which may be a source of difficulty for industrial players that never operated this type of units (ICIS Chemical Business, 2015).

Solazyme

Solazyme is a biotechnology startup founded in 2003, headquartered in San Francisco, California. The first opportunity sensed and shaped by the firm was in producing biofuels from microalgae, employing either open ponds or photobioreactors. By 2004, however, scale- up and cost issues related to these technologies led to a review in their approach and Solazyme decided to invest in heterotrophic microalgae. The core of the new technology consists in bypassing the difficulties related to converting sunlight to sugars - by simply feeding plant-based sugars - and focusing on the microalgae ability to produce oils. One of the main advantages of Solazyme's technology is the possibility to employ industrial fermentation vats already used to make antibiotics and industrial chemicals, for example, which would additionally reduce capital expenditures, since existing facilities could be leased (Xconomy, 2010).

In the following years, Solazyme has continued its efforts in biofuels, being awarded by the U.S. National Institute of Standards and Technology in 2007 (Solazyme, 2007) and by the U.S. Department of Energy (DOE) in 2009 grants to advance the microalgae biofuel technology (Solazyme, 2015). The biofuel opportunity was continued through a R&D partnership with Chevron, an oil & gas company, from 2009 to 2012, supplying marine diesel to the U.S. Navy for testing and certification from 2010 to 2011, supplying algal oil to Dynamic Fuels, LLC in 2012, among others (Solazyme, 2015). In the field of biofuels, Solazyme had leveraged partners expertise in oils processing, as in the agreement with Honeywell UOP to produce jet fuel (Honeywell, 2010).

However, Solazyme claimed it was already developing cosmetics and nutritional supplements as early as 2005, i.e. the company sensed other opportunities in markets with less volume, but higher profits than biofuels. The company's claimed strategy was to pave the way to biofuels by first scaling up production in these types of markets (Xconomy, 2013). Solazyme seized these opportunities as planned, through a variety of manufacturing partners, but also owning some production facilities. Relevant manufacturing capacity was reached through the joint venture with Bunge and the beginning of production at the Moema facility, in Brazil, with a nameplate capacity of 100,000 ton/year of oil (Solazyme, 2015).

Solazyme claims a superior capability to produce tailor-made triglyceride oils through manipulation of microalgae strains. In the last years, the company has tapped into a vast number of applications in industrial, food and personal care markets, establishing partnerships with an equally vast myriad of partners. These include chemical (e.g. BASF, Mitsui), agribusiness (e.g. Bunge, ADM) and personal care companies (e.g. Unilever, Natura), besides personal care products distributors (e.g. Sephora, QVC) (Solazyme, 2015). Solazyme holds a proprietary line of anti-aging skin care products, under the name of Algenist®. However, following the recent bottom oil prices, uncertainties in U.S. government subsidies and successive stock decrease in recent years, Solazyme decided in 2016 to abandon biofuels and industrial oils, focusing on nutrition and health products. The new company was named TerraVia (Fortune, 2016). In 2017, TerraVia was acquired by Corbion and its products and technologies are now part of Corbion's portfolio.

Amyris

Amyris is a biotechnology startup established in 2003 and headquartered in San Francisco, California. Its first research activities started in 2005 and were directed to the development of an alternative source of artemisinic acid for the treatment of malaria, through a grant from the Bill & Melinda Gates Foundation. The fundamental knowledge in artemisinic acid synthesis was related to engineering isoprenoids biosynthetic pathways in *Escherichia coli* and Amyris sensed an opportunity in providing to the pharmaceutical industry isoprenoids that were either difficult to extract from natural sources or to synthesize (IPIRA, 2015). In 2006, Amyris launched research efforts for the production of farnesene (also called Biofene®), a platform chemical, aiming at fragrance and essences markets.

However, during the company capitalization process, Vinod Khosla from Khosla Ventures (a venture capital company well involved with the biobased industry) probed the possibility of making biofuels and Amyris started efforts for producing diesel and jet fuel from farnesene. By this time, there were third parties interested in licensing from Amyris the chemicals portion of their business (those not related to biofuels), but Khosla counseled the firm not to license this option, which turn out to be a great part of their business (Lassiter et al., 2011). In the biofuels field, Amyris started collaboration with the oil & gas company Total to explore diesel and jet fuel from farnesene, culminating in the establishment of a joint venture in December 2013. One of the most remarkable steps towards commercialization of diesel was an arrangement with the city of São Paulo, Brazil, to supply renewable diesel for the city's bus fleet, realized from 2011 to 2014.

Although Amyris had pursued the biofuels path, the company also explored the platform characteristic of farnesene. Others markets currently targeted by Amyris are cosmetics (with its own line of skin-care products called Neossance™), flavors, solvents, polymers and lubricants. Many applications of farnesene, chemically transformed or not, are the result of inputs from collaborators, as disclosed by the company (Amyris, 2015a). Partners include oil & gas companies (e.g. Total), agribusiness companies (e.g. Cosan, Tonon Bioenergia), and fragrances companies (e.g. Firmenich, Givaudan). It is worth noting that Amyris also engineer microbes to produce target molecules not derived from farnesene, such as isoprene used in synthetic rubber production (advanced in a partnership with Michelin and Braskem) (Michelin, 2014) and patchouli oil used in fragrances (Amyris, 2014). Besides, the firm still have some efforts in the medicine field (Amyris, 2015b).

Amyris' basic technology for isoprenoids production through fermentation was improved along the years (including the substitution of *E. coli* by yeast), but. The company adopted a producer profile, initially relying on contract manufacturing (Amyris, 2011) and, later, constructing its own facilities. Amyris choose Brazil to locate its plants due to the availability of low-cost feedstock (sugarcane) and, in 2012, commenced operation in the Brotas facility, located in the state of São Paulo. The company still uses contract manufacturing for some operations, mainly those related to farnesene transformation (Amyris, 2015a).

In 2016, Amyris sold part of its participation in the joint venture with Total and abandoned the biofuels business which is now controlled by Total. In the last years, Amyris has focused on its technology basis in order to offer, besides farnesene, a variety of special molecules for high value markets such as cosmetics, flavors and fragrancies, and nutrition.

BioAmber

BioAmber is a startup mainly known by its involvement with bio-succinic acid, one of the most promising biobased platform chemicals listed by Bozell and Petersen (2010) and that is nowadays explored by a number of companies. The core bio-succinic acid technology used by BioAmber was developed in the 1990s by entities funded by the DOE and licensed to the New York-based company Diversified Natural Products (DNP Inc). In 2008 and 2009, an asset spin-off transaction from DNP led to the establishment of BioAmber. A key advantage of biobased succinic acid is that fermentative low-cost processes are being developed and effectively displacing its petroleum-based counterpart, used only in niche applications due to its high cost. This characteristic allows such replacement, but also the exploration of its potential as a platform chemical and as a substitute of similar chemicals, such as adipic acid, maleic anhydride and phthalic anhydride (Weastra, 2012).

BioAmber has been assessing and developing technologies for succinic acid derivatives, including PBS (polybutylene succinate, a biodegradable plastic), BDO and its derivatives, such as THF (tetrahydrofuran, an intermediate in the production of elastic fibers) and GBL (gamma butyrolactone, used as solvent, for example). For a number of these opportunities, the company decided to leverage specific technological know-how of some partners in order to build the succinic acid value chain, for example, by becoming a licensee of DuPont catalysts for the conversion of succinic acid to BDO and THF, and partnering with Evonik to further enhance such catalysts. Additionally, BioAmber partnered with Mitsubishi Chemicals, a holder of important PBS patents, to become a supplier of succinic acid used in PBS production. Even though BioAmber did not establish itself as a PBS producer, the company plans to seize this opportunity by buying PBS and making modified PBS/PLA composites, aiming initially at food applications. It will be accomplished through a joint venture with NatureWorks, one of the most important players of PLA, a biodegradable plastic derived from lactic acid (BioAmber, 2015).

BioAmber also sensed an opportunity as a producer of another dicarboxylic acid, the adipic acid. The basic technology was licensed in 2010 from Celexion and also encompasses adipic acid's derivatives such as HMD, caprolactam (both applied in nylon production) and hexanediol (used in polyesters and polyurethanes production). One of the motivations claimed by BioAmber in pursuing the adipic acid opportunity is the chemical similarity with succinic acid, which would allow the company to apply its know-how in product purification and transformation in derivatives (BioAmber, 2015).

Even before BioAmber foundation, DNP conducted scale-up of the DOE's *E. coli* technology for succinic acid, in a contract manufacturing facility located in France, from 2005 to 2010. Given some limitations related to using *E. coli*, in 2010 BioAmber entered in an agreement with Cargill to become an exclusive licensee of its yeast platform. From 2010 to 2014, BioAmber conducted commercial production using the DOE technology and also the scale-up and validation of the yeast technology, which was implemented in the Sarnia plant, in

Canada (BioAmber, 2015). The Sarnia facility was built as part of a joint venture with the chemical company Mitsui which has built and operates the plant, besides assisting BioAmber in product trading and shipping procedures. Nevertheless, the business conditions were not favorable to Bioamber in the last years and the announced its bankruptcy in 2018 (GreenChemicalsBlog, 2018).

Avantium

Avantium was founded in 2000 as a spin-off from Shell and is headquartered in the Netherlands. During its first years, the objective of the company was to apply the high-throughput R&D, initially developed by Shell for catalysis research, across a number of industries. Avantium invested significant resources to advance the technology acquired from Shell in the spin-off and structured its business around providing catalysis services to firms in the chemical and energy industries, and crystallization research for the pharmaceutical industry. This approach was expanded in 2005, when the company also started offering R&D systems (Avantium, 2007), but it remained an opportunity relatively apart from the biobased industry.

In 2006, Avantium decided to initiate proprietary development programs, including their biofuels program based on furanics. By 2007, the company declared its intention to explore the opportunity of furanics not only in biofuels, but as well as in biobased polymer monomers, specialty and fine chemicals, that would later translate in Avantium's YXY process®. Avantium intended to seize this opportunity as a licensor (Avantium, 2007).

The YXY process® was developed in the following years, culminating in the startup of a pilot plant for production of methyl levulinate, 2,5-furandicarboxylic acid (FDCA) and polyethylene furanoate (PEF) polymer, in December 2011. Avantium sensed a very important opportunity in converting FDCA to PEF polymer, which is a potential substitute of PET (polyethylene terephthalate), resulting on a partnership with Coca-Cola towards biobased plastic bottles (Avantium, 2011). Avantium later established other partnerships to develop PEF bottles, with Danone in 2012 and ALPLA, a company with know-how in PET conversion, bottle design and bottle manufacturing, in 2013 (Biofuels Digest, 2014). In order to further extend the PEF opportunity, in 2013 Avantium entered a partnership with Wifag-Polytype, a manufacturer of thermoforming and printing equipment, aiming at developing thermoforming of cups, containers and trays for food packing (Avantium, 2013). Since this opportunity had demonstrated greater commercialization potential, Avantium declared its intention to step off the exploration of biofuels (Avantium, 2015).

In 2016, Avantium announced negotiations with the chemical company BASF to form a joint venture, Synvina, to further develop Avantium's technology and to build a reference 50,000 ton/year plant for FDCA production, in BASF's site in Belgium. The aim is to build up world-leading positions in FDCA and PEF, and later license the technology (BASF, 2016). It is worth mentioning that Avantium already intended to license its YXY process® for methyl levulinate and FDCA and that FDCA polymerization to PEF can be potentially conducted in existing PET reactors, reducing the need of investments in an entirely new polymerization assets (Plastics Technology, 2014).

Metabolix

Metabolix is a spin-off from Massachusetts Institute Technology (MIT) founded in 1992 aiming at producing polyhydroxyalkanoates (PHAs, a biodegradable polyester) in genetically modified bacteria. The basic concept behind PHA production is engineering these microorganisms to yield building blocks of interest in a fermentation process (feeding sugar and other raw materials), which are later polymerized by these bacteria to polymers with desired properties. An additional research program initiated in 1998 was dedicated to produce PHAs directly in plants, such as switchgrass, in a way that after the polymer recovery, the plant residue would be used to power or biofuels generation (McCarthy, 2003). Since its beginning, sensing related strategic decisions were strongly directed to these opportunities, given the plastics pollution concerns during the 1990s and PHA's biodegradability value proposition.

Metabolix market approach was to sell PHAs as premium-priced, specialty materials, that meet both functional needs (as plastics obtained from petrochemicals) and biodegradability needs, in applications such as injection molding, casting film and sheet, thermoforming and paper coating (Metabolix, 2007). In order to supply test quantities of polymers and build a customer base, the company initially engaged in pilot and contract manufacturing, but intended to establish more definitive production partnerships to access financial resources and production capabilities. In 2004, Metabolix entered in a strategic alliance with the agribusiness company ADM to build a manufacturing facility, which came into operation in 2008 and was located at Clinton, Iowa. By 2006, Metabolix declared business development activities along with ADM using pre-commercial amounts of PHAs polymers with about 40 prospective customers in approximately 60 different applications (Metabolix, 2006). However, less than two years after the startup of the plant, ADM decided to terminate the joint venture with Metabolix, so the later had to downsize its operations and refocused its marketing efforts to more high-valued applications (Metabolix, 2015). This change forced a reconfiguration of Metabolix's tangible and intangible assets, and sensing/shaping dynamic capabilities were once again necessary to adjust the company's business model.

Another opportunity assessed by Metabolix around 2007 was the selective thermolysis of PHA to yield hydrocarbons of interest, with three or four carbons (C3/C4). In 2012, the company conducted industrial-scale demonstration of GBL production, followed by its conversion to BDO (using a conversion process available), and laboratory-scale production of acrylic acid (Metabolix, 2013).

Through 2015 and early 2016, Metabolix continued dedicated to finding new applications for PHA biopolymers, mostly as performance additives and for uses requiring functional biodegradation. Since the ending of the joint venture with ADM, market development was being conducted using the product inventory from the Iowa facility or produced in contract manufacturing. Metabolix also planned to spin-out its crop science program and suspend work in the C3/C4 chemicals field (Metabolix, 2015). However, the struggle to market PHAs led the company to divest this business in the second half of 2016, to focus on its crop science program, which involves improving crops yields (Metabolix, 2016). The firm was renamed as Yield10.

4.2. Factors impacting flexibility in business model experimentation

From the multiple case studies, we were able to identify two main factors impacting the flexibility in business models experimentation: the technological possibilities of the firm and the nature of the product. These factors are depicted below.

4.1.1 Technological possibilities

The basic motivation for entrepreneurs to found startups could be roughly described as the recognition of distinct capabilities that would allow them to deploy innovative products or services, i.e., upon which a successful business could grow. Therefore, one of the first things a startup needs to identify when designing a business model is their market segments (Chesbrough, 2010). This inquiry is straightly aligned with the technological possibilities of the firm, which in turn, can be initially analyzed from the strategic focuses we devised in the beginning of this study.

Allocated with a strategic focus of technology manipulation, Solazyme continuously expanded its target markets relying on its capacity to engineer microalgae and to obtain tailor-made oils. The firm's strategic decisions related to expanding the number of partnerships were largely enabled by its technological capabilities. In other words, being capable to adapt its technology favored sensing opportunities by addressing different markets and allowed different business models to be tested (from high-volume, commodity biofuels, to low-volume, specialty skin-care products). The other company we have selected with a strong focus on technology was Genomatica. Despite its clear capabilities on technology manipulation, the case study revealed that the company business model is basically unchanged since it decided to engage in the biobased industry (being a developer and licensor of technologies for molecules already produced by the petrochemical industry, and partnering with established companies of this industry). In this manner, one of the main differences between Solazyme and Genomatica is their strategy in respect to the variety of markets targeted. While Solazyme experimented in business model design by adapting to different markets, Genomatica strategic decision to focus on existing intermediate chemicals currently restricts its business model. Even so, Genomatica's technological capabilities position the company well in the still infant biobased industry, by drawing the interest of multiple established companies.

Amyris and BioAmber, involved respectively with the platform chemicals farnesene and succinic acid, have demonstrated great flexibility in business model design. Since platform chemicals are by definition chemical building blocks underexplored, there is a variety of possible market segments targeted. For instance, Amyris portfolio of products derived from farnesene includes biofuels, cosmetics, resins and even farnesene directly sold to third parties. Similarly, BioAmber is a supplier of succinic acid, but also aim to produce GBL (used as solvent), THF (intermediate in the production of elastic fibers) and modified PBS/PLA composites polymers used in food applications, for example. Some possible drivers for choosing market segments in the case of platform chemicals are the know-how possessed by the startup, difficulties associated with accessing complementary assets and the firm business strategy.

Finally, allocated with a strategic focus on final products, Metabolix demonstrated difficulties to flexibly experiment in business model design. The versatility of a final product could be mainly attributed to its properties, allowing its employment in a certain array of applications. Although Metabolix PHA polymers may present interesting properties, suiting them to users' necessities has shown to be difficult and major uses were not identified in our study. It is important to highlight that Avantium's initial technological possibility has shown to be a platform chemical (FDCA), but the final product PEF is a major component of the firm's strategic decisions. When focusing on this product, the flexibility of Avantium in business model design experimentation has shown to be limited, largely depending on some prominent partnerships, such as Coca- Cola, Danone and BASF.

The three general strategic focuses proposed by Alves et al. (2014) and that we initially adopted in the present study does outline important differences regarding sensing/shaping dynamic capabilities. Exploring the manipulation of technologies to yield different products and/or platform chemicals facilitate sensing opportunities, since opens the possibility of targeting different markets, conferring a potentially advantageous degree of flexibility to startups. Such flexibility derives from the usual necessity of reviewing components of business models, like cost structures, value capture logics and the forms of articulation with partners. On the other hand, focusing efforts on products that have, to some extent, experimentation restrictions (such as final products), may hinder firm's business model testing.

After evaluating technological possibilities and which offerings can be advantageous in an opportunity sensing perspective, firms can envision how they will position in the value chains and the types of development efforts they will need to engage in. Our analysis stresses that these processes are related to the product nature, discussed in the next section.

4.1.2 Product nature

This factor refers to the drop-in or non-drop-in characteristic of the target products, but with certain distinctions from the established definitions. Drop-in products were defined as biofuels or other bioproducts that can be used in replacement of fossil-based products requiring no adaptation in distribution infrastructure, transformation or use equipment, i.e., drop-in products are able to integrally use the complementary assets in-place. This concept is being extensively employed in the biofuels and bioplastics fields, where complying with existing technical specifications is a major component to avoid significant investments in specific assets (Oroski et al., 2014).

However, we identified that the term drop-in is also being used for products that are not technically identical to the existing offerings, usually surpassing the later in performance. This is the case of Solazyme's algal oils, for example (Solazyme, 2015). The interesting finding here is that these products may in fact directly replace the existing offerings and demand only minor investments in complementary assets, but also imposes some degree of interaction with users to develop their technical specifications. Although this adaptability in the offering can be an advantageous feature, companies are not able to fully deliver the product for themselves and are often required to enter in agreements with development partners. We, hence, conceptualize drop-in as: *products obtained from renewable sources whose specifications are identical to either their fossil-based counterparts or other naturally occurring molecules with low availability*[2]*, replacing these without adaptation in distribution infrastructure, transformation or use equipment.*

Summarizing, a drop-in solution deals basically with an internal effort, much directed to process engineering and optimization. As a positive feature, the startup does not need to concern with market development and its product is easily integrated downstream, if competitive in cost. However, on the downside, market exploration movements are usually very limited. The company can only insert in the different links of the established value chains, as long as proposing unconventional process technologies. This is the case of Solazyme's and Amyris' biofuels, and Genomatica's and BioAmber's drop-in intermediates, for example. These limitations are not present when a drop-in product is also a platform chemical, as is the case of succinic acid. Even though produced in reduced scale from petrochemical route, succinic acid specifications are well defined in its traditional markets. Succinic acid would only assume non drop-in characteristics if its future uses demand different specifications.

By the other hand, since non drop-in solutions are not available in the market, they demand increased market development efforts and greater company participation in articulating the value chains, which can be very time and resources consuming. Yet, the firm faces more flexibility to position in the embryonic value chains and can capture a greater share of the opportunity value by participating in the development t of derivatives downstream. Such behavior is observed in the cases of Solazyme's algae oils, Amyris' wide range of farnesene derivatives and BioAmber's modified PBS/PLA composites polymers, for instance.

While these two factors impact startups flexibility in business model experimentation, the firm profile (producing or licensing) is a business model decision that must be weighted by the opportunities and threats currently present in the industry. It is approached in the next section.

4.2 Firm profile: producing or licensing?

From the multiple case studies, two basic forms of startups engagement in the industry (profiles) stood out: producing biobased chemicals or licensing the related technologies. The product nature discussed above is a factor that shapes the possibility of licensing. Non-drop-in products are not likely to be eligible for licensing at the current stage of the industry, since licensees would have to intensively participate in market development. Therefore, to become licensors, startups need to conduct this effort, as is the case of Avantium and its partnerships with end-users to assure that a main derivative of its technology (PEF, polymerized from

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[2] It is possible to identify a movement to produce, by a new innovative route, molecules that could be obtained from renewable sources, but are difficult to extract. Examples include Amyris' patchouli oil and squalene.

FDCA) has a concrete demand. In the case of Genomatica, which deals with drop-in products, more straight-forward licensing arrangements can be undertaken, without the need (and even the possibility) of market development activities.

An interesting parallel can be drawn from the study of Arora (1997) regarding the chemical industry licensing patterns during the 20th century. After World War II, licensing became a more common practice, due to the emergence of specialized engineering-construction firms (many of which engaged in technology development) and, also, a shift in the strategy of chemical producers, that started to license some of their process innovations. The author's analyses related to the period of 1980-1990 shows that licensing was most present in sectors with large scale production facilities, relatively homogeneous products and with a large number of new plants, whereas was less common in sectors where product differentiation, products tailoring and small production scales are present. The author also highlighted that an innovator has greater motivation to license its technology in markets with more established producers, since it would have a lower market share if tried to produce (Arora, 1997). In the bioeconomy context, producer profile startups are achieving revenues mostly in low demand market segments and we have noticed no licensing movements regarding the associated technologies. These are the cases of Solazyme's and Amyris's health products, and Metabolix's PHA polymers, for example. However, technologies for drop-in products that comply with Arora's (1997) description (large scale production and homogeneous products) are in fact suitable for licensing, as is the case of Genomatica portfolio of drop-in intermediate chemicals. A mixed approach (producing some products and licensing technologies) could be possible but was not identified in our multiple case studies.

Naturally, factors other than those cited above may induce a firm to license, including: limited financial and managerial resources, lack of familiarity with international markets and anti-trust considerations (Arora, 1997). Most startups willing to become producers tackle these constraints by creating partnerships with established companies that already possess the capabilities afore mentioned, including, for instance, BioAmber joint venture with Mitsui (that build and operates its succinic acid plant) and Solazyme joint venture with Bunge. For producers, licensing may also arise as an emergent rather than a deliberate strategy (Mintzberg, 1978), following favorable business environment and/or organizational conditions.

4.3 Business model possibilities

4.3.1 Towards a comprehensive decision flowchart

This section articulates the arguments presented previously in a decision flow chart that intends to give firms a concise view of how to sequentially evaluate the potential of their technological possibilities and how they may be constrained by some characteristics of the industry. As such, the decision flow chart provides a prospective view well-aligned with sensing/shaping related strategic decisions and that can guide seizing strategic decisions. Furthermore, the flow chart is useful to organize the broad product lines that a company is involved with and point out distinctions that may lead to the establishment of different business models within the firm. Figure 1 presents this decision flow chart, including the position(s) of each company analyzed in the multiple case studies.

The initial consideration regards the technological possibilities of the firm, dividing the flow chart in three main branches. The branch "*Adaptation to Different Markets*" refers to technologies that enable startups to generate different products for distinct markets (or specific customers), as is the case of Solazyme. Sensing activities are not restricted to the possibilities of an initial product, so startups are motivated to connect with possible partners to spur innovation and find the most attractive business opportunities. Interestingly, the case of Genomatica showed that a startup may follow a focused strategy even holding important technological capabilities. The firm superior biological simulation expertise positions Genomatica well in the industry, drawing interest of many companies willing to produce drop-in chemicals and does not required Genomatica to significantly experiment in business models. The second branch encompasses platform chemicals, biobased intermediates capable of yielding a large set of derivatives, a path followed by Amyris, Avantium and BioAmber. As already discussed, adapting to different markets or exploring platform chemicals translate into enhanced business model experimentation flexibility. Their main difference is the type of product, since companies that can adapt to different markets may focus on final products, whereas the opportunity of platform chemicals may be more attractive when the firm participate in derivatives manufacturing (i.e. products with greater value). On the other hand, the path of exploring final products imposes difficulties for the startup to experiment, since it depends on products having reasonably broad properties to target different prospective markets, as evidenced by the struggles of Metabolix with PHAs. A possibility that was not identified in the multiple case studies but may occur in the industry is startups holding technologies for drop-in chemical intermediates. If the firm has limited technological capabilities to adapt to different markets, offering these intermediates would result in limited flexibility, due to its drop-in nature. Hence, the impossibility of targeting multiple markets entails lower flexibility, similarly to final products. Their main differences appear when assessing product nature and subsequently the firm profile.

Product nature is a factor associated with the adequacy of the offering in relation to the environment, which will determine the kind and extension of efforts the startup need to conduct, besides pointing how demanding the innovation is in respect to new complementary assets. This decision step applies even for platform chemicals, albeit these are in most cases intermediates not widely produced (non-drop-in). Just to reinforce this idea, succinic acid is an example of a drop-in platform chemical, which already have defined specifications in its traditional markets.

Finally, after considerations regarding product nature, a firm may assess how they will seize the opportunities (producing and/or licensing). From this point, a set of new opportunities emerges for companies either in the branch of "*Adaptation to Different Markets*" or the platform chemicals branch - the transformation of their chemicals in derivatives through further chemical conversions[3]. In the flow chart, this process is connected to the third branch (drop-in intermediate chemicals or final products). Our analysis showed a very high degree of specificity in the applications of the resulting products, which in turn allows business model experimentation flexibility similar to products in such branch. Even when producing other intermediate chemicals that may be employed by many markets (such as BDO and THF from succinic acid), business model experimentation suffers from restrictions. After chemical transformation, products are again evaluated in terms of product nature, since they may relate to the existing industrial structures in different ways.

In terms of seizing the opportunities, startups may select the most suitable way of positioning in the value chain, especially when dealing with non-drop-in products or under explored drop-in products. In all instances, choosing firms' boundaries should be evaluated on a case-to-case basis and prescriptive frameworks are available in the literature to guide decision-making (Jacobides et al., 2006; Teece, 1986).

In the multiple case studies, startups are most likely still experimenting in business model, such as Metabolix that by the time the partnership with ADM was ended was prospecting customers and applications for PHA. Similarly, Solazyme decision to abandon biofuels and industrial algal oils followed a period of experimentation with different target markets, which highlights the importance of flexibility.

Although firms' business model experimentation may be affected by these decisions, they are also subjected to the opportunities and threats presented by the bioeconomy environment. Such external conditions are constantly evolving, due to changes on regulatory frameworks, the willingness and capacity of other companies to invest on bioproducts, changing business environments of other industrial sectors that make bioproducts an interesting way to diversify (paper and pulp industry, for example), among other factors. These are not explicitly approached by the decision flow chart but are a common feature of emerging industries that will fatally lead to strategies reassessment. Moreover, startups decisions may be guided by the availability of interested partners, which many times are established companies holding important resources that the startup needs. For example, Amyris efforts in biofuels could lose strength without the partnership with Total, as was the case of Solazyme's algal biofuels. In all cases, these can be seen as emergent instead of deliberate strategies (Mintzberg, 1978).

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[3] As a very important characteristic of a platform chemical, it is possible that these transformations also expand the opportunities for firms in the "*Adaptation to Different Markets*" branch, although these types of movements were not specifically identified in our analysis.

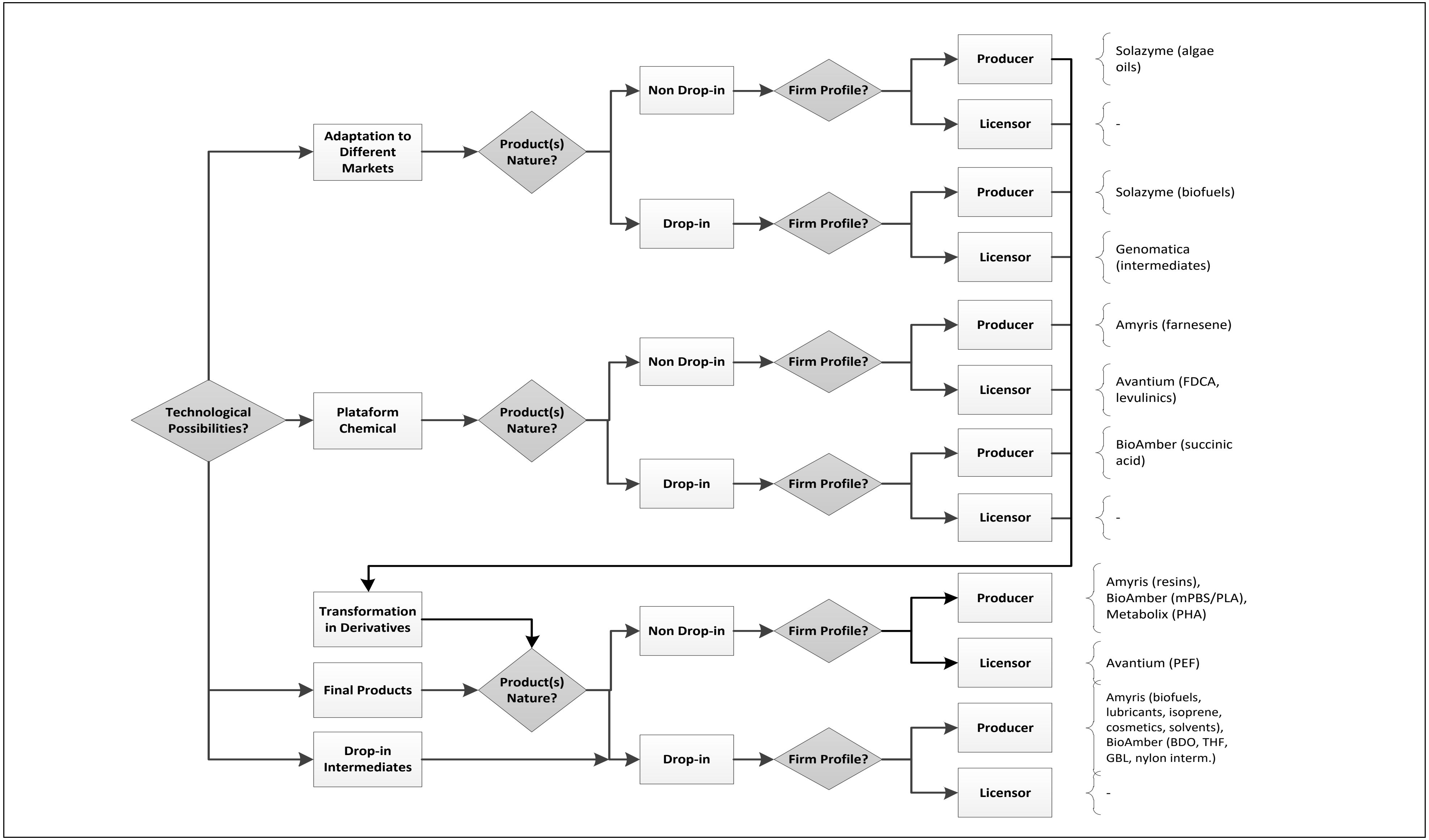

Figure 1 – Startups business model choices in the bioeconomy

4.3.2 Degree of irreversibility in business model design

Although our decision flow chart is more suitable for identifying opportunities and threats before a business model is implemented, a question that arises is how these strategic decisions may be considered irreversible in the context of startups in an emerging industry. These startups have a relatively reduced timeframe to establish themselves and attract attention of partners to support their growth, hence, some of their medium-term business model characteristics may be to a certain extent hard to manipulate.

One irreversibility that we identified is associated with the assumed firm profile, i.e., if the startup intends to become a producer or a technology licensor. The set of capabilities accumulated by a licensor tend to restrict its possibility of becoming a producer, due to the limited know-how in plant operation, products shipping, logistics and marketing, etc. For example, Genomatica has a clear strategy to remain a technology licensor and did not even foresee the necessity to build initial plants (pilot, demonstration or commercial). Similarly, Avantium intends to remain a licensor and partnered with an industrial player (BASF) to bring its technology to market. These companies tend to accumulate superior technology development capabilities, but their business models are basically unchanged during the startup initial years. On the other hand, a producer may experiment more ease to become a licensor, as did chemical and oil companies in the past (Arora, 1997).

In terms of technological possibilities, it is important for a startup to acknowledge that final products or drop-in intermediates may lead to reduced flexibility to experiment in business model design. Therefore, from a strategic point of view, keeping development programs associated with platform chemicals or continuously investing in technological capabilities may be interesting.

Aside from the startups own strategic decisions, partnerships with other companies that possess important resources (e.g. related to competitive manufacturing and products commercialization), can restrict to some degree the startups flexibility, by leading to decisions more adherent to the partner's strategies. It is difficult to clearly identify this situation only by analyzing publicly available information as in this study, but it seems quite possible.

4.4 Sensing and seizing dynamic capabilities on business model design

On Teece's (2007) framework, the business model is considered as one of the microfoundations of seizing, implying that market research (i.e. sensing and shaping opportunities) has been conducted to support conscious business model design. From our point of view, in the context of startups within an emerging industry, such perspective constrains the understanding of business model's dynamics. We noticed that sensing/shaping opportunities is a process still present when seizing an initially perceived opportunity, which can lead to reviews in components of the business model. The need of startups to capitalize and grow their businesses imposes the adoption of a "first-trial" business model, since small-scale business model experimentations that established companies could conduct (Chesbrough, 2010) are not feasible. As pointed out by Hamilton, 1990, "creating business" is a strategic imperative for an emerging firm.

We perceived that products for which market conditions are not well known (either underexplored drop-in products or non-drop-in products) demand prior opportunity seizing to support sensing and shaping activities. Startups need to define business models and commit resources to make enough quantities of their products available for testing, which can mean significant amounts considering the large demands the industry may need to supply. In this sense, startups design business models that can generate revenues to sustain operations (even if at small scale), but the firms are still realizing the actual potential of their offerings. This situation is clearly perceived with Metabolix, which was by 2003 (prior to their partnership with ADM) a 30-person company (McCarthy, 2003) using contract manufacturing to conduct market development activities[4]. The case of Amyris is another example, since the company initial venture capital investments and strategy were mainly related to converting farnesene to biofuels. The option to maintain the knowledge related to other chemicals (Lassiter et al., 2011) proved to be right and in the following years the number of markets targeted largely expanded, taking advantage of the platform characteristic of farnesene. Eventually, Amyris introduced new molecules in its portfolio, abandoned biofuels as the targeted market and become a producer of chemical specialties. Therefore, we see the startups' business model design as intimately related with sensing and shaping activities. It means that sensing and seizing can be seen as interacting with each other, in an iterative process to define the most suitable business model.

Sosna *et al.* (2010) highlight that new business models are rarely successful as firstly designed, due to struggles at both exploratory and implementation stages. At the exploratory stage, when conceptualizing the business model, decision-makers face the uncertainties of fast-changing markets and their own cognitive limitations to comprehend the environment. At the implementation stage, new business models also demand organizational realignment, requiring managers to mobilize limited resources, develop unique competencies and adjust organizational structures to promote learning, change and adaptation (Sosna et al., 2010). These difficulties seem even more pronounced if we consider the bioeconomy as a structuring environment, still in a fluid phase. Therefore, it is expected that sensing and shaping can be present after seizing an initial opportunity. From our multiple case studies, we identified startups that largely expanded their target markets in their first years but relying basically on the same innovative technologies. Examples include companies that began their participation in the biobased industry with advanced

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[4] The use of contract manufacturing or retrofit of existing units proved to be a valuable strategy for startups to minimize complementary assets expenditures, scale-up technologies and/or promote sensing activities.

biofuels, such as Amyris and Solazyme. Even sensing other opportunities, these companies needed to commit to such initial choice, taking advantage of the favorable scenario for biofuels investments.

The present paper provides extended empirical evidence to support these insights, which were also suggested by Alves et al. (2014). These insights are also in line with Amit and Zott (2014) proposition on dynamic capabilities perspective to business model design. According to this perspective, dynamic capabilities are segmented in five broad stages: observing, synthesizing, generating, refining, and implementing. *Observing* consists in a close examination of business model stake-holders interaction in meeting customers' needs, i.e., the development of a deep understanding of business model design drivers. *Synthesizing* involves the comprehension of the market gaps addressed and the forces that will shape the process of bringing solutions to customers, in a way to make sense of all that has been learned during the observation stage. *Generating* is the creation of potential business models, though not yet their implementation. *Refining*, in turn, consists in the consolidation, evaluation (according to criteria such as feasibility and desirability), small-scale experimentation of the business models generated and, eventually, narrowing the number of possible business models. Finally, *implementing* involves selecting one specific design, and making the necessary organizational and strategic adaptations. The separation between the *refining* and *implementing* stages may not be clear (Amit and Zott, 2014). The authors highlight that in both *refining* and *implementing* stages, where seizing dynamic capabilities are more prominent, the use of sensing is also required to adjust the business models. This is the pattern we have identified in our multiple case studies, mostly in the examples cited above.

5. Conclusions

With this study, we aimed to contribute to the still underdeveloped literature concerning business models dynamics in the bioeconomy context, analyzing specifically startups. These companies are important sources of technological breakthroughs but are inserted in a fast-changing emerging environment, in which some flexibility to experiment in business models design can be decisive to their survival. Through an empirical exploration of factors impacting flexibility in startups' business model design, we have identified two main factors that may impact this flexibility: (1) the technological possibilities that the startup possesses, related to the variety of markets that can be targeted and (2) the product nature, which balances products' market exploration potential with the ease to incorporate them in existing industrial structures. Therefore, we associate flexibility in business model design with the variety of opportunities that can be pursued, which many times demands changes in business model components. The assumed firm profile, producing and/or licensing, emerges as a significant business model decision that must consider the current opportunities and threats of the industry. These aspects were summarized in a decision flow chart that provides decision-makers with a practical way of assessing the paths a startup may want to pursue and their associated advantages and difficulties, besides highlighting specific characteristics that may lead to the establishment of different business models within a firm. Although not explicitly approached by the decision flow chart, we recognize that the constantly evolving business environment opportunities and threats also guide decision-making, leading to emergent strategies.

Contributing to the literature on dynamic capabilities, particularly on the interplay with business model innovation, we suggested that a disaggregated view of sensing/shaping and seizing dynamic capabilities in relation to business model design can limit the comprehension of its dynamics. The process of evolving a business model seems dependent on sensing/shaping dynamic capabilities, not only those related to seizing. We found that such overlapping of sensing/shaping and seizing occurs in the bioeconomy environment and we expect to be also present in other situations, in which products market potential is not fully understood when establishing an initial business model. These empirical findings are also consonant to Amit's and Zott's (2014) dynamic view of business model design. The authors argue that sensing and seizing dynamic capabilities are closely interwoven in the process of crafting and evolving a business model.

Another important discussion stressed in the present paper is the degree of irreversibility in business model design, especially in the medium-term. Startups in emerging industries should keep in mind factors that may contribute to low flexibility in business model experimentation and acknowledge that some offerings can be intrinsically restrictive, despite they target potentially large markets. The key point here is that flexibility can be decisive to perceive more readily deliverable offerings, which may guarantee the firm's economic growth and survival. Furthermore, the firm assumed profile (producing and/or licensing) affects the set of capabilities a startup accumulates. Medium-term irreversibility could occur if the startup pursues a technology licensor profile.

Although we were able to collect and analyze a great number of data, all findings are inferred from publicly available information and misinterpretations could occur. To minimize that issue, we have employed a multiple case study design, cross-checked crucial information and tried to properly picture companies' history of strategic decisions by searching data from the time specific movements occurred, i.e., eliminating possible biases associated with companies' current strategies.

Our future expectations are to further validate our findings by analyzing the history of other startups. We are also interested in exploring the seizing dimension on startups' strategic decisions, more specifically, the impacts of different modes of partnerships in the construction of business models. Finally, we envision the possibility of applying our decision flow chart rationale to established companies entering the bioeconomy, but factors such as competition with current businesses and availability of complementary assets are likely to alter the importance of the factors we found.

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