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Title:

How does business model redesign foster resilience in emerging circular value chains?

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1. Introduction

Global ecosystem conditions are threatened by environmental changes, related to the so-called climate crisis, interferences in nitrogen and phosphorus cycles, land-system change and freshwater use, mainly driven by agri-food production (Willett et al. 2019). All stakeholders actively involved in this production system are in the need to sustainably tackle the challenges of global warming, increasing population, and resource scarcity (Carraresi et al. 2018; McCormick and Kautto 2013; Schmid et al. 2012). New sustainability-oriented technologies enabling a circular economy do have the potential to alleviate those grand challenges, and are, therefore, increasingly being developed and progressively enter the market (Bauwens et al. 2020). According to the circular economy paradigm that promotes to limit the introduction of raw materials in the system and to reduce waste, through an effective resource valorisation which minimises the extraction of virgin resources (Fan et al., 2019), high-tech innovations enabling cascading usage of by-products to obtain valuable resources represent key drivers to foster the circular bio-economy and the overall sustainability transition (Bauwens, 2020; Haberl and Geissler 2000; Staffas et al. 2013). For example, enzymatic treatments are some of the most promising processes to degrade plant biomass into value-added products and bio-fuels (Guo et al., 2018; Koupaie et al., 2018). Also, promising enzyme variants can be used to release and recover the increasingly scarce resource of phosphorous from oil-seed press-cakes (by-products of production of e.g. rapeseed or sunflower oil – a consumer food product) to obtain polyphosphate for fertilizers and other targeted uses (Carraresi et al. 2018).

Nevertheless, the adoption of these technologies often implies industry's transformations (Geels and Schott, 2007; Nwaiwu, 2018) and the generation of new interfaces between hitherto unrelated industries which traditionally have been operating separately. This process leads to the emergence of novel value chains characterised by new cross-sectorial linkages among incumbent companies operating in distant industries and/or markets (Golembiewski et al. 2015). However, such dynamics, driven by the changing ecosystem, bring along multiple challenges (Laudien and Daxböck 2016; Teece 2010). Although these so-called “clean technologies” have the potential to enable companies' innovativeness, they are however associated with a high degree of uncertainty and missing dominant designs, since most of them are still rather immature and/or at the status of proof-of-concept or prototype (Berg et al. 2019). Moreover, once adopted, bio-based technologies might require high switching costs, different associated downstream processing technologies, acquisition of new knowledge, novel regulations and industry standards. If companies pursue this avenue and embark on a transition towards circular business models enabled by bio-based technologies, they may face competency gaps. These can be alleviated by internal development of the needed complementary assets, though it may take some time, with the risk to lose the expected competitive advantage. Alternatively, they could invest in strategic networks and alliances to access to financial resources (Maroušek et al., 2015b) and especially complementary assets (Hagedoorn and Duysters, 2002), like the knowledge needed to reach a first-mover advantage. Nevertheless, having access to extant or even new networks is challenging since these connections are at present often missing or uncoordinated. Thus, technological as well as market and regulatory uncertainties currently hamper and slow down the development of bio-based technologies and novel value chains (Carraresi et al. 2018). What is more, these developments force incumbent firms to break their established business continuity planning (Christopher and Peck, 2004) and lead to holistic industry transformation processes (Nwaiwu, 2018).

Having acknowledged that the landscape where companies currently operate is characterised by uncertainty, turbulence and risk, making it difficult to predict future scenarios, resilience represents, thus, a relevant capability for the companies aiming at maintaining competitive advantage by building a sustainable business (Carayannis et al., 2014; Roundy et al., 2017). A company is resilient when it is able to “*absorb disturbances and undergo the changes necessary to transform its essential behaviours, structures, and identity into a system that is better able to respond to disruptions*” (Roundy et al., 2017: 100). As Madsen (2020) also postulates, companies need, on the one side, to maintain organizational routines to be efficient, while, on the other side, they have to be fluid and flexible to adapt to changing circumstances. This implies that firms need to develop strategic orientation to innovation, pro-activeness, flexibility, and adaptability, to keep up with technological breakthroughs and react to environmental challenges (Carayannis et al., 2014; To et al., 2019). In these terms, resilience can also represent a dynamic capability enabling firms to sense and seize opportunities and accordingly reconfigure competencies to sustain competitive advantage (Teece, 2018).

This triggers the question of how incumbent firms can achieve the resilience that facilitates them to keep up with the current sustainability transition and to be competitive in the near future. Indeed, as value chains are moving from linear firm-centric approaches towards a circular network-centric logic involving structural changes – e.g. in the case of cascading usage of by-products (Carraresi et al. 2018) - and are, in some cases, reorganised, external relationships and entire business models need to be innovated (Amit and Zott 2001; Madsen, 2020). As the name suggests, business model innovation (BMI) entails any change operated on the business, either being the customer target, the way how an activity is performed or who is carrying out a process (Amit and Zott, 2011). BMI plays a pivotal role in fostering environmental sustainability (Bocken et al., 2014). Moreover, it can itself constitute a different innovation type based on novel behaviour involving the cascading use of raw

materials (Bröring et al. 2020). Hence, strategic flexibility is key to enter into often “path breaking” innovations needed for responding to sustainability transitions (Laudien and Daxböck 2016) and avoid a lock-in situation associated with a path dependent behaviour (Sydow et al. 2009; Vergne and Durand 2011). Nonetheless, while the emergence of new value chains in the bioeconomy has found some evidence in the literature, the discussion on business model innovation (BMI) as a process facilitating resilience and sustainability transition is still in its infancy and currently starts to be debated (Bocken et al., 2014; Dentoni et al. 2020; Evans et al., 2017; Schaltegger et al., 2012; Zucchella and Previtali, 2019). There is indeed urgency to investigate BMI, as business models reflect the structural changes which might intervene when a new supply chain is developed after technological innovation adoption; they are indeed the mediating tools to transform business strategies into practical change (To et al., 2019). Since sustainability transitions and circular economy are often technology-driven, it is pivotal that incumbent companies are aware and ready to review their businesses to respond to environmental changes. To this aim, BMI appears to be a crucial issue to be analysed. Moreover, while a quite solid literature focuses on supply chain resilience, addressing the issue both qualitatively and quantitatively (Hosseini et al., 2019), and recently opens new avenues through viable supply chains (Ivanov, 2020), to the best of our knowledge, there is still limited evidence on how resilience can be achieved through the intermediate step of innovating the business model, which bridges the way between the firm dimension and the supply chain. Last but not least, empirical cases investigating the (potential) implementation of BMI in the context of the sustainability transition in the circular economy are still scarce (Evans et al., 2017; Farla et al., 2012).

Against this backdrop the paper seeks to contribute to the body of literature on BMI by answering the question: **How does the emergence of new bio-based value chains in circular economy impact BMI?** Considering that a business model is based on value proposition (for customers), creation and capture (Amit and Zott 2001; Chesbrough and Rosenbloom 2002; Richardson 2008; Teece 2010), the paper aims to explore **how incumbent companies need to adapt their current business model towards circular designs in order to respond to ecosystem challenges.**

The analysis builds upon the case study analysed by Carraresi et al. (2018), which presents four potential value chain structure types, resulting from the cascading use of by-products - i.e. rapeseed oil press-cakes - to recover phosphate and produce polyphosphate of industrial value. This triggers the question of how the associated business models of companies involved in those value chains might be redesigned in this setting of value chain emergence.

The remainder of the paper is organised as follows: in the next section the basic concepts defining business models and BMI are introduced to provide the reader with the fundamentals of the theoretical background this paper is based on. Section 3 describes the research setting, focused on the innovative technology enabling phosphate recovery from rapeseed oil press-cakes. This technology constitutes the case study leading to potential emerging value chain structure types. Section 4 explains the approach used to collect information and data from value chain key actors. In section 5 the emerging value chain structure types are described in detail, whereas results are presented in section 6. Here we report the potential redesigns of business models in accordance with the value chain structure types stemming from Carraresi et al. (2018). Outcomes are discussed in section 7 by contrasting them with previous literature. Finally, concluding remarks are summarised in section 8 in order to highlight avenues for future research.

2. Business model innovation in the bio-based economy setting

Business models are necessary to transfer technological inventions into marketable innovations. Although the concept of business models has been extensively discussed in the literature since the 90's, it still lacks a widely acknowledged definition (Zott et al. 2011). For example, Osterwalder et al. (2005: 2) assert that a business model “serves as a building plan that allows designing and realizing the business structure and systems that constitute the company's operational and physical form”. More recently, Teece (2018: 41), recalling Teece (2010: 172), defines a business model as “the design or architecture of the value creation, delivery, and capture mechanisms [a firm] employs. The essence of a business model is in defining the manner by which the enterprise delivers value to customers, entices customers to pay for value, and converts those payments to profit”. To summarize, we purposely use the concept of Richardson (2008), who considers the role of value within the business model concept as pivotal. Accordingly, the business model is, therefore, composed by three functions - *value proposition*, *value creation* and *value capture* – namely, the company needs to formulate a product/service which customers are willing to pay for (differentiated offering, premium attributes), compared to those of competitors, deploy its resources and capabilities according to a strategy consistent with the value proposition in order to deliver that value to the buyers, and finally be able to obtain profits out of it, through successful revenue and economic models, and achieve an advantage over its competitors (Bocken et al. 2014; Osterwalder et al. 2005; Richardson 2008).

However, any business model itself can also be subject to innovation (Chesbrough 2010; Evans et al., 2017; Zott et al. 2011). Indeed, innovations aimed at an increased sustainability do not concern only technology but also processes, business models, and overall systems (Bröring et al. 2020; Evans et al., 2017; Szekely and Strebel, 2013). In this bio-based economy context, sustainable business models are focused on “*describing, analysing,*

managing, and communicating (i) a company's sustainable value proposition to its customers and all other stakeholders, (ii) how it creates and delivers this value, (iii) and how it captures economic value while maintaining or regenerating natural, social, and economic capital beyond its organizational boundaries" (Schaltegger et al. 2016: 6). Thus, business models designed for sustainability are focused not only on financial benefits, but also on generating value for the society and the environment (Bocken et al. 2014; Boons and Lüdeke-Freund, 2013; Ciulli and Kolk, 2019), and for the system as a whole (Stubbs and Cocklin 2008). They normally emerge from bio-based innovations, either being new or substitute products or processes, but can also imply themselves an intrinsic innovation, especially when we refer to required changing behaviour on behalf of value chain actors (Bröring et al. 2020). Indeed, new circular approaches, such as cascading usage of by-products, encompass the emergence of new cross-industry value chain structures which, to be sustained, need that incumbent companies change their behaviour through organizational innovation, by implementing those practices into their business model (Bröring et al. 2020). In other words, they need to adapt to their business environment, being resilient and repositioning themselves in a way to seize opportunities and stay competitive on the market (Aid et al. 2017; Madsen 2020; Teece 2018). Thus, they are challenged in breaking their current dominant path and modify their established business models, assets and structures to implement new available technologies and make them successfully work (Bocken et al. 2014; Ciulli and Kolk, 2019; Johnson et al., 2008; Linder and Williander, 2015; Schaltegger et al. 2012). That is, BMI is key to enable a circular economy (Bröring et al. 2020; Geissdoerfer et al., 2020; Hall and Wagner, 2012; Schweizer 2005).

Schaltegger et al. (2012) distinguish four phases in the process of BMI, according to the extent of the novelty in the business model's structure (value proposition, creation and capture). If the changes concern only some parts of the business model and exclude the value proposition, BMI can move from a simple *adjustment* (e.g. modification of customer relationships, infrastructure) towards an *adoption* (e.g. complying with market standards, imitating competitors) and an *improvement* (e.g. replacement of many elements of the business model). If the innovation completely changes the value proposition and, consequently, the other functions, literature refers to this as *redesign* (Mitchell and Coles 2003; Schaltegger et al. 2012;). The level of BMI in circular economy settings could depend on several factors, such as the firm propensity towards sustainability (Schaltegger et al. 2012), its extent of dynamic capabilities (Teece 2018), its willingness to change (Bröring et al. 2020; Hellström, 2007), the systemic character of the innovation (Bröring, 2008), cost constraints, and difficulty to comply with legislation (Roome 1992; Schaltegger et al. 2012;). These factors could even more easily arise when the new technology, albeit being available, is still in an immature stage, as it is the case of the new technological process for phosphate recovery.

3. Research setting: The innovative process for a new bio-based polyphosphate and the emerging value chain from cascading usage of by-products

To analyse BMI in the peculiar context of new value chains emergence in the circular economy, we draw upon Carraresi et al. (2018)¹, which presents a case of cascading usage of by-products, i.e. the recovery of phosphorus from rapeseed oil press-cakes, a side stream occurring from rapeseed oil production for food consumption.

Phosphorus constitutes an essential nutrient important for plant growth (fertilizers), as well as animal production and other end uses beyond agri-food production, such as pharmaceutical applications. Thus, its supply needs to be steady and to keep the pace of growing population increasingly demanding for food (Cooper et al. 2011). Since the phosphate rock reserves are concentrated in about five countries, with Morocco holding 77% of the whole reserve, developing alternative and sustainable ways to recover phosphorus is important to be independent from imports. Also, due to the high uncertainty of the depletion time of reserves (estimates say from 100 to 400 years left), phosphorus is one of the most significant non-renewable resources. Furthermore, phosphorus represents a threat, if its stewardship is not well managed. Indeed, it is nowadays characterised by a linear process, which continuously introduces it in the environment through phosphate rock extraction, contributing to conflict with natural cycles and to increase soil and water pollution (e.g. as undigested excreta or food waste). Indeed, more and more stringent regulations are progressively established – e.g. by the United States Environmental Protection Agency – to govern the release of phosphorus into surface waters. Moreover, it needs to be also underlined that phosphorus can be wasted in many ways – e.g. by application of composts deriving from ferrous sludge from water clarification (Maroušek et al. 2019). Therefore, a more efficient circular management and a sustainable substitute are needed to decrease the dependence from depleting mines and to face global environmental challenges (Willett et al. 2019).

The innovative technology presented in the case study allows shifting to a circular and sustainable model through phosphate recovery from cascading usage of by-products, thus renewable sources. Through this new process, the phosphate naturally contained in rapeseed oil press-cakes is mobilized by an improved variant of the enzyme phytase, which can in turn convert it to polyphosphate of industrial value. The advantages are multiple:

¹ The case study derives from the project "Efficient phosphate recovery from agro waste streams by enzyme, strain, and process engineering" (P-ENG), which has been supported by the North-Rhine-Westphalia Strategy Project BioSC (Bioeconomy Science Centre). For further information, please visit the website: https://www.biosc.de/p-eng_en

press-cakes gain extra-value as low-phosphate animal feed, leading to the associated benefit of decreasing water pollution and over-fertilization (Shilton and Blank, 2012); the extracted phosphorus is highly pure (no residues of heavy metals), and the polyphosphate that is in turn produced is renewable as completely derived from biological resources.

From the management viewpoint, the implementation of this new technology enabling the cascading usage of by-products presupposes that so far distinct value chains (oil-press cakes, biotechnology-enabled enzymes, feeding mix, polyphosphates) are reshaped through the formation of new relationships in a circular logic, generating a potential new value chain (Figure 1). In line with Kavadias et al. (2016) who say that new technologies can be adopted and create new industries only if a business model intervenes to connect them to rising market needs, the emergence of a novel value chain would imply that the incumbent firms involved would have to modify components of their specific business models in order to generate a new value proposition associated with the new structure. Even though the chain actors would remain the same, the opportunity to valorise the side stream of rapeseed oil production – namely the press-cakes – entails the creation of new inter-relationships crossing industrial boundaries. Formerly, the main buyer of the press-cakes was the feeding mix producer, who used them for several feed formulations, after having adjusted their nutrient composition according to the targeted breeder. If the new process of phosphate recovery would be implemented, the press-cakes would still constitute an ingredient for the feeding mix, but only after having released the phosphate, gaining one reuse loop and contributing to increase their value (Carraresi et al., 2018). In the value chain structure, this means that the press-cakes would be delivered to the actor who would invest and engage in the phosphate extraction – involving the producer of enzyme formulation into the chain - giving rise to potential four value chain structure types (see Section 5). After the extraction, the press-cakes could return to the feeding mix producer, whereas the released phosphate would generate a new flow towards the polyphosphate producer, who would have in turn the possibility to create a new value proposition for a bio-based product formulation.

[Insert Figure 1 about here]

To implement this innovative circular logic of the phosphate value chain the three components of the linear business model (Richardson 2008) would face several changes. Concerning the **value proposition**, out of this new process, two main offerings emerge: a new variety of polyphosphate and a new form of press-cakes. They have inherent advantages, which firms could offer to customers, generating value. The new variety of polyphosphate is completely bio-based, it allows an efficient reuse of agri-food by-products, it is not contaminated by heavy metals, and it enables the reduction of phosphate extraction from rock mines, decreasing the dependence from non-renewable resources. The new form of rapeseed oil press-cakes has a lower content in phosphate, favouring a better digestibility for animals fed with these ingredients in the meal-mix, and leading to a consequent lower water pollution and over-fertilization (related to animals' excreta). Hence, the business models need to change to account for the increased sustainability when positioning the phosphate, which most likely is not for all market segments (product-market combinations) equally of value (i.e. only a few customer groups might pay a "green price premium").

Referring to the **value creation**, it entails the resources and capabilities, and the activities that companies need to develop to make the value tangible and let them achieve revenues at the end (e.g. logistics measures, transportations, building of industry clusters, knowledge acquisition). Therefore, value creation results from new inter-firm relationships arising among chain actors. It is not a "stand alone" autonomous innovation but rather has a systemic character depending of different actors' willingness to participate in a circular business model (Bröring, 2008; Bröring et al., 2020; Teece, 2010). These relationships would be established in the upstream and downstream part of the emerging value chain and would be different according to the actor investing in the extraction technology in the different chain structures.

In terms of **value capture**, the new inter-relationships encompass high information and monitoring costs to establish networks among actors involved in the emerging value chain. Moreover, this new technological process is characterised by a high asset specificity (Williamson, 1979), since it is strictly connected with the type, quality, and quantity of the materials processed, and with their sources (Lin et al., 2013; Strøm-Andersen, 2020). Subsequently, this technology leads, on one side, to a value added for the final products, ensuring profitable advantages for the chain members, but, on the other side, entails high transaction costs to be covered and an integration effort among players to capture the revenues.

4. Methodology

Due to the paucity of prior research in the domain of resilient business models, this study takes an exploratory perspective based on Glaser and Strauss (1967) grounded theory approach, applied to the case study of phosphorus recovery from agri-food by-products. To explore this case study (Eisenhardt and Graebner, 2007; Glaser and Strauss, 1967; Yin, 1994), expert interviews have been conducted with four key companies of the emerging value chain (producers of [1] polyphosphate, [2] rapeseed oil and resulting press-cakes as by-products, [3] biotechnology-enabled enzyme formulations, [4] feeding mix), from which we applied an inductive theory-

building approach (Eisenhardt, 1989). The generated data constitute the basis for a series of studies planned to progressively investigate - during the aforementioned project - different managerial issues arising from the adoption of new technologies and the emergence of novel value chains (Table 1). Five managers have been interviewed in a timespan ranging ca. 30 to 90 minutes for each interview. Interviews have been conducted at the phone with a manual transcription of answers, enabling a content analysis. They have been structured in three parts: i) description of the project, process and potential benefits; ii) information about companies, and their current business model; iii) open questions to explore the opinions of respondents about the new process and the possible effect on the current value chain. Moreover, results have been triangulated with secondary data sources of the chain actors in question (i.e. press-releases).

The companies are based in Germany, in the western regions of North-Rhine-Westphalia and Rhine-Palatinate, and have been chosen due to their significance and market coverage in their respective value chains.

[Insert Table 1 about here]

5. Novel value chain structure types in the production process of bio-based polyphosphate

According to the chain actor who would be engaged in the phosphate extraction and release from rapeseed oil-press cakes, four potential chain structures can emerge (Carraresi et al. 2018). Table 2 summarises the implications for each chain actor.

In the *first chain structure type* the phosphate extraction is carried out by the polyphosphate producer, who would then invest in a bioreactor needed for the process. This structure is characterised by new interrelationships across different sectors. The polyphosphate company needs to open new flows backward in the chain to obtain the raw materials for the new process, namely oil press-cakes and enzyme variant. Therefore, it has to network with the rapeseed oil representatives, to receive their by-products, and with the biotech industry to buy the needed enzyme formulation to release the phosphate from the rapeseed press-cakes. After the phosphate extraction, the polyphosphate company has to deliver the press-cakes to the feeding mix industry, generating new interrelationships forward in the chain as well. This in turn implies that the sectors of rapeseed oil, biotechnology, phosphate, and feeding have to converge and new cross-industry connections among firms need to be built enabling the emergence of a cross-linking value chain.

In the *second chain structure type*, the rapeseed oil company extracts the phosphate from its press-cakes. In this case, new relationships have to be established - again both backward and forward - between the rapeseed oil company and, respectively, the biotech company providing the enzyme formulation, and the phosphate company buying the polyphosphate produced. Although an established relationship already exists, the feeding mix producer could obtain press-cakes with lower phosphate content than usual, needing in turn a slighter or no treatment with phytase to reduce the phosphate content and balance the mix. However, this structure would also entail the cooperation among the hitherto separated sectors of rapeseed oil, phosphate and biotechnology.

In the *third chain structure type*, the feeding mix company would be the responsible of the phosphate release. It would have to buy the press-cakes and the phytase, not requiring any new relationship. However, the feeding mix company would have to heavily invest in bioprocess-engineering to account for the treatment of press-cakes and the enzymatic release of phosphorus in a novel bioreactor. Hence, the new flow is constituted by the forward integration with the phosphate processor who would buy the polyphosphate generated in the new process.

Nevertheless, these three novel value chain structures imply several challenges, dominated by the new investment that the company engaging in the extraction would have to do, encompassing fundamental changes in the business model (Carraresi et al. 2018), which this paper aims to explore.

Therefore, a *fourth chain structure type* has also been mapped out, implying the intervention of an intermediary chain agent, hence, a new focal company that owns the expertise to run the bioreactor for phosphate extraction and acts as a “collector” of new material flows. The new chain actor serves to concentrate the press-cake supply, receive the enzyme variant formulation and run the process in order to deliver the new polyphosphate to the phosphate company. This basically entails an entire logistical change, since new interrelationships need to be established between the intermediary and the incumbent companies, but at the same time enables to reduce the emerging challenges, such as missing know-how, logistic costs, difficulty of network creation and integration among incumbents.

[Insert Table 2 about here]

6. Potential business model transformations according to different novel value chain structure types

Even though the new technology has an immature technology readiness level (TRL 3 “proof of concept”) (OAST, 1991; Sadin et al., 1989), interviews allow envisaging potential BMI, according to the value chain structure types emerged and explained in section 5.

For each value chain structure type, results are analysed from the viewpoint of the company who would engage in the new technological process of phosphate extraction (Table 3) and would encounter major changes in the three components of the business model adhering to the definition of Richardson (2008).

[Insert Table 3 about here]

Value chain structure type #1

In the first value chain structure type, the polyphosphate producer (A) is assumed to engage in the phosphate extraction (Table 3). It has the closest access to the phosphate market, being thus able to successfully derive the value from the value proposition to the creation and capture. Indeed, it is well positioned regarding market capabilities, as it is familiar with the target customers, and can shape the **value proposition** accordingly. The BMI is, thus, associated with developing new product-market combinations and a novel “more sustainable” positioning. Offering a bio-based form of polyphosphate enables the polyphosphate producer to expand its product portfolio and even reach new target customers, e.g. those sensitive to environmental issues. Looking at the second pillar of the business model framework – the **value creation** - respondents from the polyphosphate company explained that they need to acquire new resources, both tangible (i.e. bioreactor, equipment, human resources) and intangible (know-how) to run the new process; further, they have to set up new cross-industry relationships and concerted work with novel suppliers and customers, respectively represented by rapeseed oil producers, enzyme providers, and new customer targets for bio-based ingredients. Regarding the third pillar - the **value capture** - respondents highlighted that there would be information and monitoring costs to select an appropriate number of press-cakes suppliers to achieve a steady supply to cover the polyphosphate demand and transportation costs to carry and funnel this supply to the same factory. The same happens with buyers of press-cakes after the extraction, representing by-products with an extra-value for the feeding industry; in this case, the polyphosphate producer needs to afford increasing costs to manage these new transactions. In particular, the polyphosphate processor, being an incumbent with an established knowledge of the phosphate market, is facilitated in marketing and communicating the added value and the specificity of the new bio-based polyphosphate, applying for example a “sustainability label” (Rubik and Frankl, 2005). This novel attribute could indeed differentiate the new product and make it more attractive for those environmental-sensitive customers which may be willing to pay a premium price for a bio-based ingredient for their final industrial applications (i.e. emulsifying agents, toothpastes, soaps and detergents) (De Chiara, 2016; Johnson, 2003; Kitchin, 2003). This would contribute to cover the investment made by the company and generate revenues, while improving its environmental image. Overall, the polyphosphate processor would also need to deviate from its extant path and somehow step-wise substitute its current business model.

Value chain structure type #2

In the second value chain structure type, the rapeseed oil producer (B) is supposed to extract the phosphate. Therefore, for this actor, the BMI related to the **value proposition** would be especially connected to a new positioning for the press-cakes with a lower content in phosphate after the extraction. Being already used to manage this kind of by-product from rapeseed oil production, by simply delivering it to the feeding industry, the rapeseed oil producer would benefit even more by having the possibility to add one loop in the process allowing extra-value generation from a side stream. In this way it can position the press-cakes focusing on the better “performance” that this ingredient would have as fundamental ingredient in the animal feeding mix, improving both animal wellbeing and the consequence on the environment.

Referring to **value creation**, part of the raw materials (press-cakes) would already be on premises - as a side stream of the main production process - though respondents mentioned that a higher amount seems to be necessary to cover the phosphate demand. Therefore, the rapeseed oil producer would need to start new horizontal intra-industry relationships with other competitors to concentrate the amount of press-cakes and have a better bargaining power afterwards for both the bio-based polyphosphate and the press-cakes low in P-content.

Value capture will be affected by the investment costs associated with the equipment and know-how necessary for the new process. Nevertheless, revenues will be connected to the different placements of the bio-based polyphosphate and the press-cakes low in P-content. For the former, the rapeseed oil producer said that it would not enter the phosphate market, but rather sell the new polyphosphate formulation to a new-to-it customer (polyphosphate processor), generating in turn a new value chain linkage, bridging two different industries. For the latter, rapeseed oil producers could profit by press-cakes with a higher value added, due to the low phosphate content, and would need to achieve a good bargaining power against the feeding industry. This value chain structure is interesting in two respects: first, in order to capture the value, a mechanism of *coopetition*² (Bengtsson and Kock 2000) among rapeseed oil producers seems relevant to generate a critical mass, making the entire investment worthwhile and enabling the production of a competitive amount of polyphosphate appealing for polyphosphate processors; second, the supply concentration and the new investment enable the valorisation of by-products, which might even become a primary core business for some rapeseed growers and processors.

² Coopetition is defined as “the dyadic and paradoxical relationship that emerges when two firms cooperate in some activities, such as in a strategic alliance, and at the same time compete with each other in other activities” (Bengtsson and Kock 2000: 412).

Value chain structure type #3

In the third chain structure type, the feeding mix producer (D) is considered the one investing in the new extraction process. From the interview, it has emerged that the feeding mix producer could profit from this new P-recovery technology, by substituting extant processes, becoming themselves outdated or at least less profitable. Indeed, BMI concerns the new **value proposition** related to the possibility to develop innovative feeding mixes starting from lower phosphate content press-cakes. While traditionally the feeding mix producer bought press-cakes in order to formulate targeted low-P feeding meals itself, now through the new technological process, it would gain an extra-advantage by purchasing a modified enzyme variant enabling to remove phosphorus from the press-cakes before formulating the feeding-mix, obtaining a greater benefit. Starting from low-P press-cakes would allow the feeding mix producer to develop targeted meals by focusing on the content of other nutrients and developing innovative formulations responding to the needs of different breeders. As in the previous case, the polyphosphate generated from the process would be sold to the polyphosphate producer who has already access to the market.

BMI also entails **value creation**: first an investment in terms of tangible and intangible resources (respectively, bioprocessing reactor and know-how) is necessary; second, vertical relationships would need to be established with additional press-cakes suppliers - to make the investment profitable - and with new polyphosphate processors - to place the value-added polyphosphate on the market - considering that the value proposition is changed as well.

Value capture relates with the revenues shared in different measures along the value chain, even though the player investing and engaging in the P-release process would be able to drive more value its way, and have key and pivotal role, as in the previous structures.

Value chain structure type #4

Finally, the fourth conceived chain structure, envisaged by all respondents, is characterised by the involvement of a new agent, here called “collector”. It would already own the necessary equipment and know-how for the new process and would have to coordinate the entire chain, by funnelling the raw materials and delivering the final products to the respective markets. Basically, in this structure, the incumbents would not have to completely redesign their business model, but rather they need to engage in a business model improvement (Schaltegger et al., 2012). The **value proposition** relates, as before, to the new bio-based form of polyphosphate and the low-P rapeseed oil press-cakes, providing different benefits to the respective customers, mainly concerning environmental sustainability; differently from the previous structure types, these new products are processed by a new actor entering the value chain. Therefore, despite being specialised in the bio-based process of phosphate recovery, the new actor does not have a direct access and a deep knowledge of the markets relevant for the outcomes of the bio-based process. It would need, thus, a strict collaboration backward and forward along the chain to position the products on the market and to formulate a successful selling point. In terms of **value creation**, then, new inter-firm relationships need to be built: the press-cakes and the enzyme variant formulation have to be delivered to the new customer – the “collector” - who centralises the process and, in turn, distributes the polyphosphate and the low-P press-cakes, respectively to the polyphosphate producer and the feeding mix company which are already operating into those markets. Therefore, the “collector” would likely be a start-up (i.e. a spin-off), owning technology and know-how, and operating a technological platform across extant different chains. **Value capture** is associated with the possibility to overcome the challenges of BMI for the incumbents, by involving a new actor, who could exchange its resource endowment with revenues deriving from the commercialisation of value-added products. It could play as first mover and exploit the value of the process through the establishment of a cross-industry network, facilitating the interplay among actors and the *industrial symbiosis* (Chertow 2000), namely a network where single companies become inter-dependent of one another (Bocken et al. 2014), capturing the value created in the process.

7. Discussion and managerial recommendations

The interviews revealed that the adoption of disrupting and sustainable innovation entails the intersection of sectors in multiple layers leading to a deconstruction of traditional established value chains, by now outdated. Indeed, potential new specialised competitors, alone or in networks, enter the market with better practices, leading to new value chain emergence and in turn BMI, and triggering value redistribution among players (Bresser et al. 2000; Galvão et al, 2020; Schweizer 2005). Therefore, incumbents need to develop resilience to absorb disruptions and grasp opportunities stemming from bio-based and circular economy transition (Carayannis et al., 2014; Roundy et al., 2017; Geels and Schot, 2007).

In the case study at hand, the emergence of the novel circular value chain, enabled by the bio-based process of phosphate recovery, encompasses for the incumbent firms a business model *redesign*, according to the classification proposed by Schaltegger et al. (2012).

Referring to our research question, according to the value chain structure types potentially arising, BMI implies different issues, such as value migration among actors, new cross-industry relationships, networking, and new

marketing strategies. The chain actor who would engage in the new bio-based phosphate recovery process in each of the four structure types presented - either being an incumbent (type #1 to #3) or a new agent (type #4) - would drive BMI by acting as an *orchestrator* (Schweizer 2005; Zucchella and Previtalli, 2019), who “concentrates on one or few steps of the industry value chain, has a high total revenue potential and access to all relevant complementary assets via collaborations” (Schweizer 2005: 47). Indeed, as our results show, the new process disrupts the extant value chains, implying that the incumbent company investing in the new technology would need specific resources and capabilities which can either develop internally or source-in (Hagedoorn and Duysters, 2002). Our results revealed that internal development is challenging, mainly due to cognitive barriers (Nooteboom et al. 2007), path dependence (Sydow et al., 2009), and resistance to break the current business for a new one, confirming previous evidence in the literature (Bröring, 2010; Ansari and Krop, 2012; Bergek et al., 2013; Bohnsack et al. 2014; Ciulli and Kolk, 2019; Halme et al., 2012; Strøm-Andersen, 2020). Indeed, as recent reviews demonstrate, several factors hinder the implementation of sustainable solutions, such as the amount of the required investment and the data availability about the efficiency of the process in terms of sustainable performance (Fan et al., 2019), the missing corporate ‘green’ vision and poor alignment between that vision and strategic actions, and the overall economic viability (Galvão et al, 2020). Thus, a more feasible way to get engaged with such sustainable innovation seems to be the establishment of new relationships with novel suppliers and buyers. A solid cross-industry network among companies belonging to hitherto separated value chains is pivotal to successfully exploit complementary assets supporting value proposition, creation and capture and could be conducted even in parallel with the current business to explore new opportunities (Carayannis et al., 2014; Teece, 1986). Thus, our respondents would need to build a network enabling a good value exchange, not only in terms of products and revenues, but also, and even more importantly, in terms of knowledge and intangible resources, and facilitating efficiency achievement (Dentoni et al., 2020; Madsen, 2020; Strøm-Andersen, 2020; Weber and Khademian, 2008). Indeed, as Urbancova (2013: 93) notes “*innovativeness founded on knowledge and the ability to respond to a turbulent environment is perceived as a source of profitability and success of organisations in the present competitive environment*”. In our case, incumbents could start developing partnerships and/or joint ventures, both backward and forward in the chain, to ease the acquisition of complementary resources and capabilities and to ensure sustainable consumption. Indeed, on the one side, establishing partnerships may help to decrease the risks associated with supplier selection and evaluation (Dědina and Šánová, 2013) to secure a steady supply of by-products and ingredients, namely press-cakes and enzymes (Ciulli and Kolk, 2019; Dentoni et al., 2020; Strøm-Andersen, 2020). On the other side, strict and reliable customer relationships increase the awareness about innovative sustainable solutions (i.e. bio-based polyphosphate) and the likelihood of customer acceptance (Tunn et al., 2019), in turn, enhancing the profitability of the investment in the new technology and, overall, favouring sustainability transitions. To facilitate the creation of new cross-industry relationships, several grants fostering “green businesses” are increasingly published and funded, either by public or private sources (e.g. the Green Deal research program of the European Commission). Those calls for proposals stimulate the collaboration between research and industry, have a multidisciplinary character, facilitate the access to funding to enterprises and start-ups, playing thus a relevant role in the implementation and adoption of new technology and BMI.

Through cross-industry partnerships, BMI enhances companies’ resilience. Indeed, those forward-looking companies able to recognize opportunities in sustainability transition, to manage complementarities and to absorb disturbances going through necessary modifications to respond to disruptions (Roundy et al., 2017) can play the role of chain orchestrators and drive the change (Zucchella and Previtalli, 2019), as it would be the case of the companies engaging in the phosphate extraction from rapeseed oil press-cakes. Since business models are a sub-set of the whole ecosystem where they are embedded, BMI encompassing cross-industry relationships and aiming at sustainability transition also contributes to support the resilience of the entire system, as Dentoni et al. (2020) also assert.

Furthermore, to overcome the uncertainty revealed by our interviewees to adopt the new technology of phosphorus recovery, BMI could even be implemented step-wise (Laudien and Daxbock, 2016; Tunn et al, 2019). Indeed, incumbent companies could run parallel the circular business models together with the current linear one - developing ambidexterity capacity on the business model level (O’Reilly and Tushman 2013). This solution might be appropriate for value chain structure types #1 and #2, where, respectively, the polyphosphate producer and the rapeseed oil producer, being already in the market, would have more chance to explore a new segment and test a new business model, before leaving the old one – thus the only gradually migrate the linear business model to a circular one. Indeed, firms could “cross-subsidize” the new business by using the stable revenues from their traditional business model (Ciulli and Kolk, 2019; Sosna et al., 2010). Adding a new value proposition coexisting with the current one would allow firms to diversify the revenues and smoothly adapt themselves to the new market whilst maintaining the past one (and ideally leaving it step by step) (Hacklin et al. 2018). A similar process is also suggested by Johnson (2010), who illustrates that, once a company has identified an opportunity, it could overcome the inherent challenges by, first, developing a preliminary business model to be tested and, gradually, implementing it through a series of low-risk actions which managers could learn from, and accordingly shaping the definite new business model. A further suggestion is to analyse new business

models “away from the base organization until they reach critical mass and can be integrated” (Slywotzky and Linthicum 1997: 10), in order to avoid that the old designs still remain fundamental and pull the new ones out hampering their birth and implementation (Slywotzky and Linthicum 1997). This vision is also in line with the recent perspective of implementing a “semi-circular” economy to gradually adapt to change (van den Bergh, 2020). As biological ecosystems need long time to evolve and absorb disturbances, the same way time is needed to formulate accurate circular economy policies and to design business models accordingly.

The introduction of a new value proposition coexisting with the current business would offer, therefore, a new perspective of how BMI might work in sustainable designs, i.e. when new value chains emerge from the cascading usage of by-products. In this way, our study contributed with a practical case to BMI literature, which still lacks empirical examples (Evans et al., 2017).

Nevertheless, a pre-requisite for a successful business model redesign is the development of dynamic capabilities enabling companies to sense and seize opportunities (Teece 2007 and 2018), associated with the acquisition of knowledge about technologies available (Strøm-Andersen, 2020). Without exploring the competitive environment and adapting their business accordingly, companies might risk a failure (Doz and Kosonen 2010). Thus, it would be recommended that, especially the polyphosphate, the rapeseed oil and the feeding mix producers are aware of the new processes available for a better and more sustainable phosphorus stewardship. If they would explore the chances offered by enzyme variants and new technologies available, they could be less sceptical and it could be more feasible to implement one of the BMI proposed, either related to value chain structure types #1, #2 and #3. In the process of BMI to anticipate and capture the value migration, it is pivotal that companies invest time and engage in a learning process to develop absorptive capacities (Cohen and Levinthal, 1990; Strøm-Andersen, 2020), understand which competencies are outdated or no longer necessary, what is valuable nowadays for customers, how they can differentiate themselves, which new capabilities are needed (Slywotzky and Linthicum 1997). That is why business models need to be continuously innovated, especially in dynamic environments where fundamental modifications happen (Achtenhagen et al. 2013), such as the emergence of new value chains and the shift towards circular designs, e.g. those based on new technological advances (Bauwens et al. 2020).

Outcomes also revealed that there are cases where incumbents are not willing to invest in the new equipment for the bio-based process, leaving the “white space”³ (Johnson 2010) to a new agent, here called the “collector” (see Table 3 and value chain structure type #4). The collector acts as a *market maker* who “creates an entirely new step in the industry value chain, has a relatively low total revenue potential and has a high market power as an innovator, so that it generates demand for its business” (Schweizer 2005: 48). It owns the necessary resources and coordinates the whole process by delivering the final products to the respective customers. Although in this case incumbents would not face a complete business model redesign, but rather an *improvement* (Schaltegger et al., 2012), they would need to adapt their customer targets and some process characteristics to comply with the new design, once more underlining the systemic character of sustainable innovation (Rohrbeck et al., 2013). This scenario would well apply to those incumbents who see the potential of the new bio-based technology, but are not yet ready to break the whole current business. Therefore, they can rely on the “collector” to complement what they miss, partially adjust and strengthen their business model, and participate in the sustainability transition, paving the way for its diffusion (Ciulli and Kolk, 2019).

This case also proposes a different contribution of how the emergence of a new value chain affects BMI: even when incumbents do not show the sufficient resilience to absorb disruptions, they can still profit from the benefits generated by a new actor and shared among all players through *industrial symbiosis* (Chertow 2000), as the chain structure type #4 reveals. Indeed, this process could lead to a common advantage for firms, associated with geographical proximity, by facilitating the exchange of resources at inter-firm level and decreasing logistic costs. From an environmental management viewpoint, this process would generate a sort of industrial ecosystem (Frosch and Gallopoulos 1989) based on interdependent resource flows and waste streams, and close location of complementary assets, leading to a better efficiency, as each player specialises on its core competence. In the bio-based economy domain, where our specific case study is inserted, constituting such a system for recovering phosphate and producing bio-based polyphosphate could also have relevant implications at regional level supporting the sustainability transition, through the creation of “islands of sustainability” (Wallner and Narodoslowsky 1996; Wallner et al. 1996), which might offer an opportunity of diversification for regional systems.

Further, from the ethical viewpoint, though not analysed in details, it has to be mentioned that the reluctance manifested by respondents towards this new technology is related to their limited awareness of a possible resource scarcity, in particular of phosphorus. Thus, missing risk perception respect to benefit perception of a sustainable resource is affecting adoption and overall slows down sustainability transition. Even the polyphosphate producer, who manages a joint venture for the utilisation of phosphate mines in North Africa, did

³ A white space is defined by Johnson (2010) as an opportunity in the market that a company can undertake only by modifying its business model. For example, a firm might want to launch its innovation to the market. Firms which are not able or willing to occupy these white spaces can miss potentially valuable opportunities, which could instead be taken by other firms, which own already that core competence (Johnson 2010).

not really feel the environmental problem about phosphorus stewardship and reserve depletion, confirming previous tendencies found in the literature concerning technologies impacting with the environment (Maroušek, 2013a; Maroušek et al., 2015a).

Limitations of the study are associated with the fact that the analysis has been conducted on a case study basis with a limited number of interviews. Also, we did not carry out neither process efficiency analysis nor financial, comparing the conventional value chain with the four hypothetical structures. The results of the study need also to be taken with care as we did not analyse in depth the operations and logistics of the supply chain. Therefore, our findings are explorative and can serve as a blueprint for future studies to provide a preliminary idea of how new business models could be redesigned in light of the emergence of new value chains in a bio-based circular economy domain.

Accordingly, our outcomes open different avenues of further research as follows:

- Referring to the specific case analysed, it may be worthwhile to consider new technologies enabling a better efficiency in the rapeseed oil extraction (Maroušek, 2013b; Maroušek et al., 2014), which could even improve the yields in the phosphorus concentration of the press-cakes; the whole recovery process may in turn result more promising and profitable, enhancing the probability of innovation adoption.
- An enlargement of the sample of case studies involving other industries and including different new technologies will enable a review of possible business models fostering the circular economy.
- A financial analysis of the payback period of the investment could enable to shed light on ethical issues, namely how long the payback period would allow companies to invest in the bioreactor to make their process circular and more sustainable (Maroušek et al., 2015a).
- A scenario analysis based on recent advances in digitalisation could provide a data-driven support to decision makers in case of innovative disruptions (Ivanov and Dolgui, 2020; Maheshwari et al., 2020). Data analytics applied to the supply chain management would help to investigate the dynamic sensing capability of managers and the resilience of value chains in case of potential implementation of sustainable technologies.
- An analysis of cross-sectoral partnerships extended to other actors which are not part of the value chain but could participate in the network – such as academic institutes, research centres, governmental institutions, non-profit organisations, professional associations – would also contribute to evaluate how those stakeholders could enhance the innovation adoption through knowledge acquisition, participatory learning and incentives and to assess the effect of BMI to the resilience of the whole ecosystem.
- A study investigating the micro-foundational dimension (Felin et al. 2015) of individual manager perspectives could be interesting to analyse, for example, how companies might break their stable hierarchies and create individual network structures to become more innovative, agile and fast, and/or to evaluate how micro-actions and intra-firm interactions are able to mediate macro-organizational activities, like BMI.
- Since circular logics can also entail a rebound effect associated with behavioural changes (Bauwens et al. 2020; van den Bergh, 2020), it could be worthwhile to investigate the effects of psychological scenarios as well as institutional factors connected with the implementation of those technologies on circular economy transition, which could actually reduce the environmental benefits.

8. Conclusions

With this study we contribute to the emergence of novel value chains and the effect of those on BMI. The paper aimed to pursue a path of analysis of the phenomenon of new bio-based technologies' adoption at organizational level. After a first study exploring the macro level of the emergence of new value chains (Carraresi et al. 2018), the present paper took a further step into a micro-level of single companies and investigated the implications of the emergence of new value chain structures on BMI, in the case study of a new technology to recover phosphorus from rapeseed oil press-cakes and produce a polyphosphate of industrial value.

Despite the necessity to adopt bio-based technologies to face global environmental challenges, multiple issues for companies arise, associated with the difficulties in breaking existing paths and exploring new opportunities. Results highlighted that, although firms have underlined a general low or uncertain profitability of the new technology, possible BMI might be considered in the medium run, entailing a complete business model redesign. Thus, the new value proposition needs to reach new customer targets more sensitive to sustainability issues and/or to enhance the awareness towards bio-based technological solutions into extant customers. Value creation and capture highly depend on the coordinating role of the chain actor willing to invest in the new equipment for phosphate extraction, which become the focal company within the emergent value chain. According to the four chain structure types that emerged from the analysis, this role can be played either by an incumbent company or by a new agent entering the market.

Moreover, it has been found that the implementation of the new technological process analysed has two main managerial implications on the BMI, depending on the chain actor who would invest in the equipment to recover phosphorus. If the new recovery and release process is carried out by an incumbent (see chain structure types from #1 to #3), it requires additional investments in highly specific assets together with new cross-industry relationships to complement missing resources and knowledge about such technological breakthroughs available on the market. The incumbents' necessity to engage in a process of exploratory, transformative and exploitative

learning also explains their reluctance in implementing innovative processes. If a new actor – the ‘collector’ – enters the emerging value chain (see chain structure type #4), the process of BMI is mediated and moderated by a company who holds both tangible and intangible resources. This last possibility seems not only to catalyse the implementation of the sustainable innovation, but also could facilitate the market entry of start-ups and foster the collaboration with spin offs and technology developers, closing the gap between industry and research.

The insights we generate seem very valuable as they may inform also other cases of “emerging circular economy” which are based on novel value chains and their interplay with BMI. Our paper also demonstrates, with a practical case study, that BMI based on cross-industry relationships increases the interconnectedness among actors, allows resource exchange and improves knowledge transfer, by enabling in turn incumbent companies to adapt their business through mutual collaboration. In this way, we can even assert that the capacity of a company to adopt a new technology and, thus, be resilient by adapting its business model to innovation disruptions, also fosters the resilience of the other new chain members. Thus, the emerging value chain and resulting BMI reinforce the sustainability transition. Closing the loop, sustainable BMI would contribute to the resilience of the whole ecosystem as well. This also confirms the outcomes of Bröring et al. (2020) who found that re-organizing and innovating business models constitute a specific innovation trajectory towards sustainability transition and is worth, therefore, to have dedicated policy attention as a peculiar innovation type.

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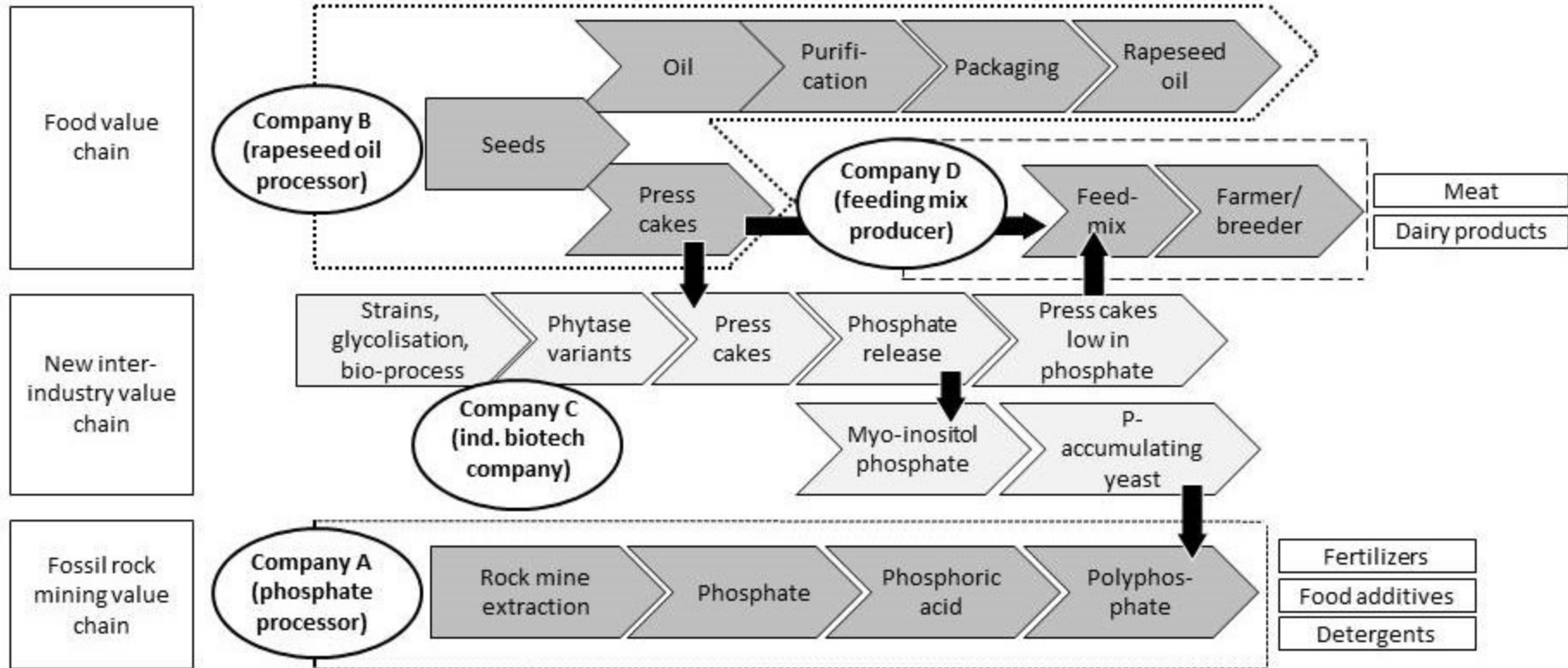


Table 1 – Data generation and progress of analyses in the framework of the P-ENG project

Respondent	Current business	Research Question 1	Research Question 2
Company A	Phosphate processor operating a joint venture for the mine extraction of rock phosphate. Producing then polyphosphate compounds serving as targeted ingredients for industrial purposes (B2B)	RQ1.1) What are the main challenges related to the emergence of novel value chains that confront chain actors in the case of phosphate recovery from agricultural by-products?	RQ2.1) How does the emergence of new bio-based value chains in circular economy impact BMI? RQ2.2) How incumbent companies need to adapt their current business model to react to ecosystem challenges stemming from the emergence of circular bio-based value chains?
Company B	Rapeseed oil processor producing seed oil and press-cakes. Seed oil (e.g. rapeseed) sold in the food market directly to final consumers through retailers (B2C). Press-cakes serve as ingredient for feeding mix formulations (B2B)	RQ1.2) Which novel value chain structures might emerge in the case of phosphate recovery from agricultural by-products?	
Company C	Industrial biotech company formulating enzyme variants for feeding mix formulations targeted according to the meal specific requirements (B2B)	→ <i>Questions addressed in the paper Carraresi et al. (2018).</i>	→ <i>Questions addressed in the present paper</i>
Company D	Feeding mix producer developing and delivering feeding mix formulations to pig breeders		

Source: adapted from Carraresi et al (2018)

Table 2 – Value chain structures arising from implementation of P-recovery technology

Design of the value chain		Engagement in the P-extraction	Implications for incumbent chain actors				
			Phosphate processor (A)	Rapeseed oil processor (B)	Industrial biotech company (C)	Feeding mix producer (D)	
Value chain structure type	<p>Diagram 1: Value chain structure type 1. The process starts with seeds from Company B (rapeseed oil processor) going to Oil, Purification, Packaging, and Rapeseed oil. Simultaneously, seeds go to Press cakes, which then go to Company D (feeding mix producer) for Feed-mix, and finally to Farmer/breeder. A bio-process (Company C, ind. biotech company) is integrated, receiving Strains, glycolisation, bio-process and Phytase variants. It takes Press cakes and produces Phosphate release, Myo-inositol phosphate, and P-accumulating yeast. This bio-process also produces Press cakes low in phosphate, which go to Company D. The bio-process also produces Polyphosphate, which is supplied by Company A (phosphate processor) via Rock mine extraction, Phosphate, and Phosphoric acid.</p>	1	Phosphate processor (A)	<ul style="list-style-type: none"> - Investment in equipment / know-how - Selection press-cakes suppliers - Selection phytase enzyme supplier - Concentration press cake supply - Production of low-P press-cakes as by-product - New customer base for press-cakes - Production new bio-based polyphosphate 	<ul style="list-style-type: none"> - New customer base for press-cakes 	<ul style="list-style-type: none"> - Production new phytase variant - Change the customer base for phytase 	
	<p>Diagram 2: Value chain structure type 2. The process is similar to Diagram 1, but the bio-process (Company C) produces Polyphosphate, which is then supplied to Company A (phosphate processor). The flow from Company C to Company A is indicated by a dashed arrow.</p>	2	Rapeseed oil processor (B)	<ul style="list-style-type: none"> - Availability of a new bio-based polyphosphate 	<ul style="list-style-type: none"> - Investment in equipment / know-how - Selection phytase enzyme supplier - Production new product (polyphosphate) - New customer base for polyphosphate - New market segment (phosphate/chemical) 	<ul style="list-style-type: none"> - Production new phytase variant - Change the customer base for phytase 	<ul style="list-style-type: none"> - New ingredient available (low-P cakes) - Smaller need of phytase for the feed

Table 2 (cont.) – Value chain structures arising from implementation of P-recovery technology

Design of the value chain		Engagement in the P-extraction	Implications for incumbent chain actors				
			Phosphate processor (A)	Rapeseed oil processor (B)	Industrial biotech company (C)	Feeding mix producer (D)	
Value chain structure type		3	Feeding mix producer (D)	- Availability of a new bio-based polyphosphate		- Production of new phytase variant	- Investment in equipment and know-how - Production of a new product (polyphosphate) - New customer base for polyphosphate - New market segment (phosphate/chemical)
		4	New agent / Collector	- Availability of a new bio-based polyphosphate	- New customer base for press-cakes	- Production of new phytase variant - Change of the customer base for phytase	

Source – Adaptation based on Carraresi et al. (2018)

Table 3 – BMI consequent to the emergence of different value chain structure types

<i>Business model innovation</i>					
	<i>Chain actor</i>	<i>Value proposition</i>	<i>Value creation</i>	<i>Value capture</i>	
<i>Value chain structure types</i>	<i>1</i>	<i>A*</i>	<p>New form of bio-based polyphosphate, highly pure</p> <p>Rapeseed oil press-cakes with low P content</p> <p>Potential new customer targets</p>	<p>New relationships with suppliers of rapeseed oil press-cakes and enzyme variant</p> <p>New customer relationships for the low-P press-cakes</p> <p>New tangible (equipment) and intangible (know-how) resources</p>	<p>Improvement of company's environmental image / Sustainability label</p> <p>First mover advantage / differentiation / premium price for bio-based polyphosphate</p> <p>High transaction costs / high asset specificity</p> <p>Reduced P-rock's extraction and transport costs compensate those for new resources</p>
	<i>2</i>	<i>B*</i>	<p>Rapeseed oil</p> <p>Rapeseed oil press-cakes with low P content</p> <p>New form of bio-based polyphosphate, highly pure</p> <p>Potential new customers</p>	<p>New horizontal relationships with rapeseed oil producers</p> <p>New relationships with suppliers of enzyme variants</p> <p>New customer relationship for bio-based polyphosphate</p> <p>New tangible (equipment) and intangible (know-how) resources</p>	<p>High transaction costs / high asset specificity</p> <p>Premium price for press-cake due to P-content</p> <p>Costs for new resources</p>
	<i>3</i>	<i>D*</i>	<p>New feed-mix with lower P content</p> <p>New form of bio-based polyphosphate, highly pure</p> <p>Potential new customer targets</p>	<p>New customer relationship for bio-based polyphosphate</p> <p>New tangible (equipment) and intangible (know-how) resources</p> <p>New processes/formulation to adapt to the new enzyme variant</p>	<p>Improvement of company's environmental image</p> <p>Costs for new resources</p> <p>High transaction costs / high asset specificity</p>
	<i>4</i>	<i>Collector*</i>	<p>New form of bio-based polyphosphate, highly pure</p> <p>Rapeseed oil press-cakes with low P content</p>	<p>New relationships with suppliers of rapeseed oil press-cakes and phytase variant</p> <p>New customer relationship for polyphosphate and low-P press cakes</p>	<p>First mover advantage / differentiation / premium price for value added products</p> <p>High transaction costs / high asset specificity</p>

(*) Chain actor responsible for the new process of phosphate extraction

BM = Business Model

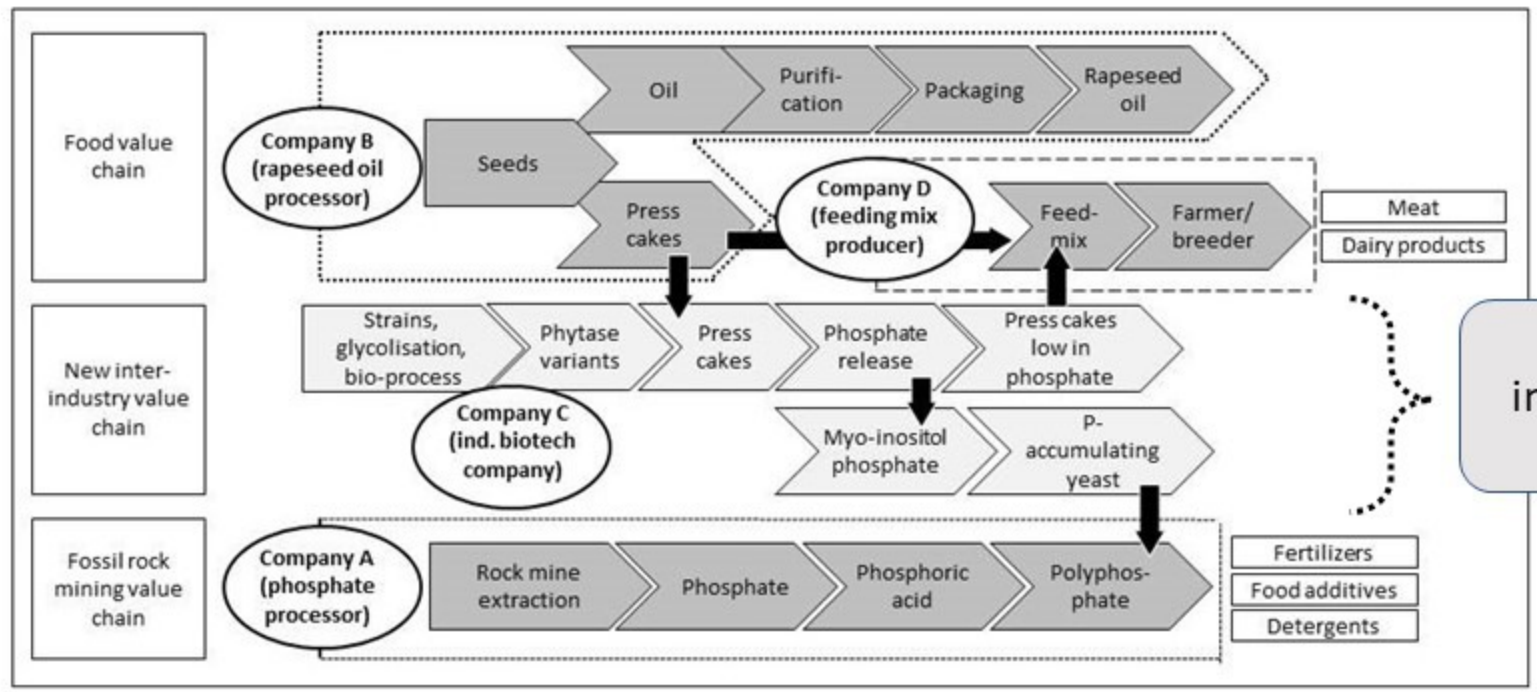
P= Phosphate

Source – Own elaboration

Emerging cross-industry value chain

Reuse and valorization of agricultural byproducts

- Extant value chains are **reshaped**
- New **cross-industry interface**



Sustainable innovative recovery process

New sustainable business models associated to the investment into a new sustainable technology

Incumbents need to develop exploratory, transformative and exploitative learning together with new cross-industry relationships

New actors can enter the emerging value chain to mediate and moderate business model innovation by owning both tangible and intangible resources, and catalysing technology implementation