Business Models in Process Industries: Emerging Trends and Future Research

Abstract: This article reviews the literature on business models in process industries. The review reveals that the business model concept has gained an increasing amount of attention in process-industrial research, but it also shows that the literature exhibits a lack of construct clarity and that it is developing in different domains, depending on the perspectives scholars have taken to study business models in process industries. Specifically, while innovation management scholars have explored the relationship between technological innovations and business models as well as the process and outcomes of business model innovation, scholars from the domain of production management have focused on value chain (re)configurations and taken a system-based perspective to consider boundary-spanning exchanges with key stakeholders in the design of business models. However, despite variance in the perspectives, the review further shows that works in these divergent domains point to a family of emerging themes and to common ideas that have not been explored together. This allows us to identify the particularities of business models in process industries and develop a definition of process-industrial business models, which extends prior business model literature into the process industry context. Furthermore, we synthesize these connections to develop an agenda for future, cross-disciplinary research on business models in process industries that assists cumulative theorizing and subsequent empirical progress.

Keywords: Business Model; Business Model Innovation; Process Industries; Production Management; Innovation Management; Literature Review

1. Introduction

The process industries include economically important sectors such as chemicals, food and beverages, mining and metals, pharmaceuticals, and utilities (Lager, 2010). In contrast to manufacturing industries that assemble products in a discontinuous process, the process industries use "raw materials (ingredients) to manufacture non-assembled products in an indirect transformational production process often dependent on time. The material flow in production plants is typically of a divergent v-type, and the unit processes are connected in a more or less continuous flow pattern" (Lager, 2017, p. 203).

The complex transformation processes as well as interdependencies between unit processes in these industries demand a holistic and integrative view on the series of relationships between raw materials and the customer (Brown et al., 2005; Frishammar et al., 2012; Hullova, Trott and Simms, 2016). This is echoed by Samuelson and Lager (2019, p.

135) who argue that "the homogenous nature of products manufactured in the process industries, as well as the intimate coupling between raw materials, production processes and products […] necessitates a well-integrated production and product design philosophy". Since production systems influence innovation in process-industrial contexts, a close integration is especially relevant for innovation and production management (Bauer and Leker, 2013; Bergfors and Larsson, 2009; Floyd, 2010; Frishammar, Lichtenthaler, and Richtner, 2013; King, 2009, Lager et al., 2017).

Yet, despite the importance of closely integrating innovation and production activities, research on production and innovation management in process industries is often surprisingly disconnected. Looking at product and process innovation, Hullova et al. (2016, p. 929), for example, note that the "understanding of complementarity between these two types of innovative activities has been a rare theme in the innovation literature." Similarly, Säfsten et al. (2014) observe that prior research has tended to overlook the interface between technology development, product development, and production. On the one hand, there is hence a need for "an improved intra-firm production/R&D collaborative approach" (Lager and Rennard, 2014, p. 148). On the other hand, there is a need for an inter-firm collaborative approach because innovation and production activities in process industries increasingly extend beyond the boundaries of a focal firm and are performed by different actors across the various material transformation stages (e.g., Adner and Kapoor, 2010; Herzog and Leker, 2010; Sarkar and Costa, 2008; Kirschbaum, 2005; von Delft et al., 2019).

Prior research has made several attempts to address this gap. Bruch and Bellgran (2014), for example, proposed the concept of production system portfolios at the corporate level, eventually offering an interactive approach between product innovation and production system innovation. Another line of inquiry focuses on inter-firm relationships (e.g., Lager and Frishammar, 2010; Rosell, Lakemond, and Wasti, 2014). Lager, Tano and Anastasijevic

(2015), for example, demonstrate the importance of collaboration between process equipment suppliers and users during the innovation and the production stages. Scholars have also considered the management of globally dispersed innovation and manufacturing resources in process industries (Kinkel et al., 2014), and used a capability-perspective to show that success in global markets depends on alignment and coordination of innovation and manufacturing activities across locations (Slepniov et al., 2014).

Jointly, these perspectives are insightful and attest to the theoretical and managerial benefits of integrating innovation and production activities in process industries. But these perspectives leave unexplored another concept that may bridge the gap between the research domains of innovation and production management in process industries: the business model.

The business model describes the "design or architecture of the value creation, delivery, and capture mechanisms" of a firm (Teece, 2010, p. 172). On the one side, the business model establishes the customer value proposition, describes how value is created, and how a focal firm connects to transaction partners such as customers, complementors, and suppliers (Baden-Fuller and Mangematin, 2013; Frishammar and Parida, 2019; McGrath and MacMillan, 2000). On the other side, it defines how value is delivered, monetized, and shared among transaction partners (Johnson et al., 2008; Teece, 2010). The business model, therefore, refers to the overall *gestalt* of interlinked boundary-spanning transactions and interdependent activities that enable value creation, delivery, and appropriation: the business model defines what key activities are performed, how those activities are linked, and who performs activities across the various production and material transformation stages (Amit and Zott, 2001; Zott and Amit, 2008). The focus here is on the key activities that create value for transaction partners and the focal firm (Zhao et al., 2020). For a chemical company offering coating solutions to customers in the automotive industry, manufacturing-related key activities might include processes to produce the various paint layers and their combination

into the final automotive paint; revenue generating activities might include charging fees for value-added services and cost-per-unit invoicing, where the car manufacturer pays for each perfectly coated body rather than for the amount of paint delivered; and R&D-related activities might include processes to continuously optimize production and to develop new application processes that help customers save costs.

From a practical perspective, business models have become a hot topic in management thinking in the in the process industries in recent years. The life science company DSM, for instance, is investing in new technologies like machine learning to create new business models for personalized nutrition solutions (DSM, 2019). In the pharmaceutical industry, GSK and Pfizer are exploring new business models that move away from linear pharmaceutical value chains to new value ecosystems which put the patient at the center and are built on partnerships between firms that collaboratively create value (Chesbrough, 2007; Frankenberger, Weiblen and Gassmann, 2014; von Delft, 2018).

Overall, the business model is a holistic and integrative concept that combines a product-market view with a production system view. The former is sometimes referred to as 'listening to the voice of the customer', which is captured in the design of an effective customer value proposition. The latter is sometimes referred to as 'listening to the voice of production', which is reflected in the key activities in a business model, performed by the focal company or partners, to transform raw materials (ingredients). The business model is hence "a structural template of how a company connects [with] factor and product markets" (von Delft et al., 2019, p. 2). As a holistic and integrative concept that spans firm boundaries and considers interdependencies between R&D and manufacturing activities, the business model has the potential to bring research on innovation and production management closer together, and it might stimulate cross-functional attitudes and behaviour for innovation and production management in the process industries. The potential of the business model as a

unifying framework is also highlighted by Storm, Lager and Samuelson (2013, p. 253), who argue that firms in process industries must "not only be excellent at developing commodities or innovative functional products; they must also be able to manufacture them in a competitive cost structure within the framework of a proper business model."

The purpose of this article, then, is to provide the first comprehensive review of the literature on business models in process industries, as well as to document challenges in that literature, and to identify emerging themes that can serve as a basis for future cross-disciplinary research on the topic. The review is structured as follows: we begin by describing how this review has been carried out. Next, we review the literature on business models in process industries by examining it from the lenses of innovation and production management. Finally, we develop a definition of process-industrial business models, discuss emerging themes, and conclude with recommendations for future research on business models in process industries.

2. Method

Given the importance of a conjoint approach to innovation and production management in the process industries (Floyd, 2010; Frishammar et al., 2013; Hullova et al., 2016; King, 2009; Lager et al., 2013; Lager et al., 2017) and the potential of the business model concept to stimulate cross-functional attitudes in R&D and manufacturing (Foss and Saebi, 2018; Lanzolla and Markides, 2020; von Delft, 2018; Zhao et al., 2020; Zott and Amit, 2010), the disciplinary focus of this literature review is innovation and production management.

Following other literature reviews (e.g., Maddux et al., forthcoming; Zott et al., 2011), we took several steps to conduct this review. First, we searched for articles on business

models published in leading[1] innovation management journals, namely Journal of Product Innovation Management, Research Policy, R&D Management, and Technovation, and production management journals, namely IEEE Transactions on Engineering Management, International Journal of Operations and Production Management, Journal of Operations Management, and Production and Operations Management, during the period January 1998 to December 2018. This search, conducted using Elsevier's Scopus database, returned 125 publications that contained the term business model in the title or abstract.

An initial analysis of these articles revealed that not all focus on process industries. We therefore excluded articles that are not relevant to process industries. In case of empirical studies, we excluded those that focus on business models in non-process industrial settings such as automotive or retail. In case of conceptual work, we only included articles that are relevant to business models in process industries, using the following criteria: (1) the article must deal with an issue important in relation to the architecture of value creation, delivery, and capture of a process company (e.g., the decision to reconfigure an established business model is important since it is typically irreversible and requires substantial commitment of resources); (2) the article must deal with a topic that extends beyond those relevant to single functions and ordinary operational issues of process companies, i.e., the topic of the article must be of strategic nature, requiring a concerted, cross-functional response by the company (e.g., transition to circular economy business models). For example, we included conceptual work on business models and digital transformation since digital transformation changes how companies in process industries create, deliver, and capture value; as such, the digital transformation is simultaneously an opportunity and a strategic challenge for firms in process industries and their established business models. We further confirmed this assessment by

[1] We used the journal ranking of the Chartered Association of Business Schools (available at: https://charteredabs.org/academic-journal-guide-2018/) to identify the leading journals in each discipline.

reviewing industry magazines and reports as well as interviewing five experienced managers from different process industries (chemicals, pharmaceuticals, and utilities) with responsibility for business model development. For example, in the context of the chemical industry, articles published in industry magazines CHEManager and Chemistry & Industry frequently identify digital platform business models as an emerging trend. Moreover, reports published by consulting companies also discuss digital transformation and the corresponding emergence of new platform business models. In a recent report, EY, for instance, concludes that "the digital revolution will inherently move the chemicals industry toward new business models […] platform businesses, which are potentially decentralized, automating most of the work" (EY, 2018). This assessment was confirmed by one of our interviewees, a senior manager at a Germany-based chemical park operator, who commented: "digitalization allows us to create new business models […] we are currently exploring a new platform business based on predictive maintenance, where we create value for customers by combining chemical plants, data, and services in a new way."

After applying these steps, our initial sample comprises 42 articles. Reading these articles in depth, we became aware of further works that are relevant to our review that led us to expand our search to other management journals, namely Creativity and Innovation Management, International Journal of Innovation Management, International Journal of Production Economics, International Journal of Production Research, Journal of Cleaner Production, Technological Forecasting and Social Change. This search resulted in 102 relevant articles, which we added to our initial sample.

In a final step, we included relevant work published in leading academic and practitioner-oriented management journals, namely the Academy of Management Journal, Academy of Management Review, Administrative Science Quarterly, California Management Review, Harvard Business Review, Journal of Management, Journal of

Management Studies, Management Science, MIT Sloan Management Review, Organization Science, and Strategic Management Journal. We also included articles on business models in process industries published in Long Range Planning. Our final sample comprises 167 articles. An overview of the sample is presented in Table 1. As Figure 1 suggests, the number of publications in the said journals on business models in general as well as on business models in process industries has grown over time, especially in the period between 2010 and 2018. Reading all articles, we classified each article into the domain of innovation management and production management respectively. The following section presents the business model concepts used in these articles and discusses the emerging themes in each domain.

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3. Literature review

3.1. Business model definitions

Before we delve deeper into domain-specific business model research, we begin with a brief review of how the business model concept is defined in process-industrial research. On an abstract level, process industry scholars define the business model as the *way in which a firm creates value* (Matos and Silvestre, 2013), the *organizational and financial architecture of a business* (Bocken, Short, and Evans, 2014), *the logic of a business idea* (Schrauder et al., 2018), *the activity systems and governance arrangements between the firm and external actors* (Kamuriwo, Baden-Fuller, and Zhang, 2017), *the agreements among value chain members about who perform which function and how economic rewards are allocated* (O'Connor and Rice, 2013), or simply as *how a firm makes money* (Wu and Pagell, 2011). Others refer to the business model as a "description of processes through which organizations

implement their competitive strategies and create value" (Bini, Bellucci, and Giunta, 2018, p. 1161), or as a "simplified representation of the elements of a complex organizational system and the interrelation between these elements" (Geissdorfer et al., 2018). Some scholars further specify the business model concept by enumerating its key components. Most of these studies build on existing business model definitions, such as Osterwalder and Pigneur's (2010) *business model canvas* (e.g., Spector, 2011; Wainstein and Bumpus, 2016; Reymen et al. 2017; Kiel et al. 2017), which consist of nine building blocks, or Amit and Zott's (2001) *activity system perspective* (e.g., Visnjic, Weingarten, and Neely, 2016; Hellström et al., 2015; Olofsson, Hoveskog, and Halila, 2018; Ritala et al., 2018; Wei, Song, and Wang, 2017), which includes the design elements of activity content, structure, and governance to describe how firms create and capture value. Other scholars introduce new definitions by outlining a set of components that constitute a firm's business model: Spring and Araujo (2009), for example, refer to the business model as a framework that consists of the network structure, how transactions are made, how revenue models and incentives interact, and how capabilities are accessed, while Managematin et al. (2003) propose that a business model describes the market a firm targets, its expected growth, its modes of governance, and the organization of its activities. Meanwhile, Boons and Lüdeke-Freund (2013) propose value proposition, supply chain, customer interface, and financial model as components of a business model. An overview of definitions is presented in Table 2.

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Yet another set of studies explores a related, but distinct concept: business model innovation. Bocken et al. (2014, p. 44) refer to business model innovation as "changes in the way the organization and its value-network create, deliver value, and capture value (i.e., create economic value) or change their value propositions", while Tsvetkova and Gustafsson

(2012) define it as the "re-consideration of wealth creation mechanisms and the underlying structure of contemporary production and consumption" (p. 247). Najmaei (2016) suggests that business model innovation is "a type of organizational innovation in which firms identify and adopt new business models" and differentiate it from product innovation, since "it targets the organization of productive activities rather than their outputs" (p. 2). Moreover, some studies rely on existing business model innovation definitions. Shomali and Pinkse (2016), for instance, refer to Markides (2006, p. 20), who defines business model innovation as "the discovery of a fundamentally different business model in an existing business."

Remarkably, however, many process industry scholars do not explicitly define the business model (or business model innovation) concept at all. In our sample, 22% of the studies from the domain of production management do not offer any definition of the concept and 43% of articles from the domain of innovation management do not define what a business model is, giving rise to a number of different interpretations.

3.2. Business models, operations, and production management

Research on process-industrial business models in the domain of production management is characterized by two complementary ideas. The first is that the business model reflects the configuration of the value chain, thus describing what organizational activities and operational processes need to be performed to ensure the reliable and scalable delivery of value. The second is that the business model is a boundary-spanning system of activities, which embeds the firm in a network of inter-organizational relationships, thus capturing complex interdependencies between the firm and its customers, suppliers, and other stakeholders.

Considering firms' value chains, production management research has described and categorized business models in various process industries (Annarelli, Battistella, and Nonino,

2016; Bini et al., 2018; Gaiardelli et al. 2014; Hannon, Foxon, and Gale, 2015; Iles and Martin, 2013; Lütjen, Tietze, and Schultz, 2017; Pätäri and Sinkkonen, 2014; Reim, Parida, and Örtqvist, 2015). For example, in their review of performance-based contracting, i.e., a business model for the delivery of product-service systems, Glas, Henne, and Essig (2018) find that the selection, measurement, and management of key performance indicators, such as availability and reliability, are key activities to successfully deliver the value proposition to the customer. In their analysis of business models operated in the liquid crystal display market, Chiang and Trappey (2007) find that liquid crystal suppliers operate different business models, depending on the level of product differentiation and choice of production process. Suppliers that offer customer-specific liquid crystal mixtures, for instance, operate a business model which is characterized by a series of closely integrated value chain activities and the involvement of customers in value-creating activities (e.g., co-development).

Scholars have also explored how the choice of business model has implications for the configuration of a firm's value chain (and *vice versa*). Wei et al. (2017), for instance, suggest that firms pursuing "a new business model in the digital environment […] often need to reconfigure their internal manufacturing resource combination to suit the new model", and find that manufacturing flexibility, i.e. the ability to realign and restructure production resources across the value chain, promotes both efficiency- and novelty-centered business model designs. Stoughton and Votta (2003) use the business model perspective to study value chain configurations of companies in the chemical industry. They observe that an element in product-centric business models of chemical companies can be volume-based discounting (e.g., the more liters of an additive a customer of a chemical supplier buys, the cheaper the price per liter is). This creates an incentive for "increased consumption for the buyer while requiring the supplier to sell increasing volumes to offset the decreased profit per unit of chemical sold" (Stoughton and Votta, 2003, p. 840). This choice on the revenue side of the

business model has consequences for the key processes and the key resources underpinning the business model, such as the scale of production facilities, lead times, and throughput. In contrast, service-centric business models create, according to Stoughton and Votta (2003), an incentive for reduced, and thus more sustainable, production and consumption, and it impacts the supplier's operational processes, with service elements complementing production activities. However, as Agrawal and Bellos (2015, p. 1546) note, servicizing models may lead "to a larger number of customers adopting and using a product, making servicizing environmentally inferior." To test when and why servicizing business models are both more profitable and environmentally superior to a conventional sales model, they develop an analytical model that allows the firm to choose between offering a conventional sales model, a hybrid business model that combines product sales and service options, or a pure servicizing business model. Results show that under certain conditions a servicing model is environmentally inferior for high production costs because it leads to a larger production quantity and that a hybrid business model can be both more profitable and environmentally superior. With their study Agrawal and Bellos (2015) offer a contribution to the production management literature by showing that different types of business models have different financial and environmental performance implications.

Differences in value chains and business models can also be observed in the utilities industry: Shomali and Pinkse (2016), for instance, find significant differences between the value chain configuration and associated business models of traditional electricity providers (e.g., centralized, asset-intensive energy generation) and the ones of firms relying on smart grids, i.e., using digital technologies to meet the varying electricity demands of customers, to incentivize energy saving and use of renewable energies, and to empower customers.

Another key perspective in the production management literature is the recognition of linkages between a focal process company and the larger production and consumption system

in which it operates (Biloslavo, Bagnoli, and Edgar, 2018; Boons and Lüdeke-Freund, 2013; Mansoornejad, Pistikopoulos, and Stuart, 2013; Urbinati et al., 2017). Work in this stream of the literature sees business models as market devices that connect an individual firm with various stakeholders. In this view, the business model answers, for example, how upstream and downstream relationships of a focal process company are structured and managed, eventually shifting focus towards the inter-organizational value creation, delivery, and capture constellation (Ahl et al., 2018; Bidmon and Knab, 2018; Oskam et al., 2018). Consequently, many studies in this part of the literature follow Zott and Amit (2007; 2010) and define a business model as a system of activities that spans firm boundaries (e.g., Brehmer et al., 2018; Reficco et al., 2018).

Comparing and contrasting different business models along the dimensions of openness (i.e., the extent to which firm activities in the business model are reallocated to external partners) and the integration along the product-life-cycle, Kortmann and Piller (2016) identify nine different business model archetypes operated by manufacturing firms. Their classification ranges from transaction-oriented business models, in which firm activities end with the sale of the product to the customer, over co-creating manufacturing models, where firms collaborate with external partners in development and production activities, to circular-platform business models, where products are recycled and reused. For example, according to Kortmann and Piller (2016), Beiersdorf, a manufacturer of personal-care products and pressure-sensitive adhesives, has opened its business model by integrating customers into product development activities, which enabled the firm to create more value.

A system-level perspective is also used to analyze how changes in the business model of a process company can accommodate the reconfiguration of the supply chain as a consequence of the globalization of production networks (e.g., Brennan, Tennant, and Blomsma, 2015; Chiarvesio and Di Maria, 2009), digital transformation (e.g., Moeuf et al.,

2018), or sustainable development (e.g., Petit-Boix and Leipold, 2018; Nußholz, 2018; Rajala et al., 2018; Ranta, Aarikka-Stenroos, and Mäkinen, 2018). The transition to the circular economy, for example, represents not only a significant technical challenge to process companies (e.g., adapting material cycles) but may also require systemic change, such as the transformation of interconnected and interdependent business models (Geissdoerfer et al., 2018; Veleva and Bodkin, 2018). Indeed, production management scholars acknowledge interdependencies between established business models as well as acceptance of a new business model by supply chain partners as critical for business model change (Shomali and Pinkse, 2016).

3.3. Business models, new technologies, and innovation management

The business model concept also has been addressed in the domain of innovation management. On the one side, innovation management scholars are interested in the relationship between business models and technological innovations (e.g., enzyme engineering), emphasizing the role business models play in the commercialization of technologies as well as how technological change can promote innovation in business models. On the other hand, innovation management scholars are interested in how new business models come into being and how established business models are changed and transformed, i.e., the process of business model innovation, as well as in the outcomes of business model innovation.

Grounded in early conceptual work by Chesbrough and Rosenbloom (2002), who define business models as "the heuristic logic that connects technical potential with the realization of economic value" (p. 529), the technology-focused stream in the process industry literature asks what business models companies use to commercialize new technologies, including the identification of different business model types (e.g., Lazonick

and Tulum, 2011; Mustar et al. 2006; Pätäri, 2010; Willemstein et al., 2007). For example, Mangematin et al. (2003) identify two main business model types used to commercialize biotechnology: SMEs that operate business models in niche markets tend to conduct small research programmes more or less independently, while SMEs that operate business models in larger markets tend to perform research programmes in partnership with major companies in the sector. These two business models differ in relation to resources biotech SMEs mobilize and the mechanisms by which they govern activities in the business model. Studying biotechnology firms in Italy, Bigliardia et al. (2005) identify three broad types of business models: service-based business models operated by firms that focus on performing activities outsourced by larger companies, research provider business models operated by smaller firms with scientific expertise in a specific biotechnology area, and integrated business models operated by large, diversified companies. Another typology is offered by Sabatier, Mangematin, and Rousselle (2010), who explore business model portfolios of biotechnology companies and note that "successful biotech companies have generated revenues by implementing several different business models simultaneously to serve different customers" (p. 432). Examples for business models in the portfolio, defined as "the range of different ways [biotech companies] deliver value to their customers to ensure both their medium-term viability and future development" (Sabatier et al., 2010, p. 431), are "collaboration for discovery", "technology brokering", "technology platform", and "contract manufacturing". Each model can be associated with one of the following core competencies: drug discovery, knowledge architecture, and process optimization. Another business model type is identified by Davis (2008): licensing of intellectual property. This "business model is based on licensing out the rights to their inventions to other firms, who further develop the inventions commercially" (ibid, p. 6).

Focusing on the firm level, several studies claim that business model design lies at the heart of commercializing new technologies because the business model determines how firms can create and capture the value from a technology (Anokhin, Wincent, and Frishammar, 2011; Al-Aali and Teece, 2013; Dmitriev et al., 2014; Kamuriwo et al. 2017; Toro-Jarrín; 2016; von der Gracht and Stillings, 2013). In other words, firms should not only excel in developing innovative products with superior functionality through R&D, but also be able to manufacture and market them through appropriate business models (Kappor and Klueter, 2015; Storm et al., 2013). In particular, innovation management scholars argue that it is crucial for entrepreneurs to select the appropriate business model when introducing nascent generic technologies to the market, because these technologies may have different applications and create value for various customer groups (Bower, 2003). Lubik and Garnsey (2016) suggest that the design of business models of university spinouts plays a key role in how generic and early-stage technologies are commercialized. Together, the literature suggest that firms should move beyond the technology itself and align the solution with customer needs (Bogers, Hadar, and Billberg, 2016), eventually promoting value co-creation (Borgh et al., 2012; Breuer and Lüdeke-Freund 2017; Chesbrough, 2007; de Vasconcelos Gomes et al. 2018; Frankenberger et al. 2014; Gloor and Cooper, 2007; Helfat and Raubitscheck, 2018; Li and Garnsey, 2014; West and Bogers, 2014) and creating more value by combing products with services (Bureth, Penin, and Wolff, 2010; Lovins, Lovins, and Hawken, 2007; Visnjic et al., 2016; Visnjic, Neely, and Jovanovic, 2018).

Given the role of business models in unlocking the value of technological innovations, work in this stream of the literature concludes that the fundamental challenge with technological shifts in the market is “a business model problem, not a technology problem” (Christensen, 2006, p. 48). For example, the transition to more sustainable technologies and the circular economy largely depends on whether the innovators can find

effective ways to create value for the focal firm *and* the wider community (Curtis and Khare, 2004; Despeisse et al., 2017; Esslinger, 2011; Ford et al., 2017; Jia et al., 2016). This requires firms to re-conceptualize their value creation logic and collaborate with stakeholders in the design of sustainable business models (Breuer and Lüdeke-Freund, 2017; Laukkanen and Patala, 2014). It also requires entrepreneurs to act as system builders and reconcile technological, political, economic, and social aspects of value creation. For instance, Bolton and Hannon (2016) explore the interactions between business models, energy infrastructure, and actor groups and institutions, eventually concluding that activities in a firm's business model need to be aligned with the wider socio-technical regime to realize more sustainable energy production and consumption.

Recent studies have also highlighted the role of technological change in facilitating the emergence of new business models and the transformation of established business models (Phaal et al., 2011; Sabatier et al., 2012; Tierney, Hermina, and Walsh, 2013). For example, several scholars suggest that the ongoing digitalisation has led to an increasingly complex and dynamic industrial landscape, in which digital technologies like 3D printing stimulate business model innovations (Björkdahl 2011; Jia et al., 2016; Liao, 2004; Potstada et al., 2016; Rao, 2017). Sorescu (2017), for instance, suggests that information networks and big data can fuel business model innovations, and Kiel et al. (2017) show that the industrial Internet of Things (IoT) may trigger changes in production, which can also lead to the emergence of new value proposition and subsequent modifications of other elements in a firm's business model (e.g., customer relationship management). According to Calia, Guerrini, and Moura (2007), technological innovations may not only result in a competitive product but also expose firms to new networks (e.g., venture capital) that enable the transformation of business models. This view is supported by Teece (2018a), who suggests that firms need to explore new ways of profiting from innovation in the digital economy.

Firms in process industries can, for example, consider the development of platform business models (Helfat and Raubitscheck, 2018).

The second stream in the innovation management domain emphasizes the complex and dynamic nature of designing business models and examines the process and outcomes of business model innovation. This stream views business model innovation as a type of innovation itself and investigates how business model innovations come into being. This includes both the process of creating a new business model (e.g., by a biotechnology start-up) and the reconfiguration of an established business model (e.g., by a large pharmaceutical firm in response to changes in customer preferences) (Dmitriev et al. 2014; Täuscher and Abdelkafi, 2017). Early work in the field has often assumed business model innovation is a linear process of rational conception and causal reasoning (e.g. Cavalcante, 2014). More recent studies, however, find that business model innovation may be a nonlinear process, requiring firms to engage in market-driven experimentation and on-going adjustment of an early business model design (Gudiksen, 2015; Markides and Oyon, 2010; O'Connor and Rice, 2013). Studying a UK-based producer of petroleum additives for the fuel and lubricants industry, Sinfield et al. (2012, p. 90), for example, find that the firm's "goal in the business model experimentation process was to leverage its product technology and know-how and create a list of profitable new opportunities that fit with its core competencies." From a range of business model options, the company eventually selected two and implemented them "from inception to commercialization within 18 months, a time frame that is unusual in an industry as asset-intensive as petrochemicals" (Sinfield et al., 2012, p. 90).

Experimentation with new business models and adaptation of existing ones may also require companies to actively involve key stakeholders such as customers and suppliers, in the innovation process (O'Connor and Rice, 2013; Miles et al., 2009). It may also require firms in process industries to develop organizational capabilities related to the identification

and exploitation of opportunities for business model innovation (Brink and Holmén, 2009; Schoemaker, Heaton, and Teece, 2018; Zook and Allen, 2011). Moreover, building on Casadesus-Masanell and Ricart (2010), research in this stream considers business models as the intermediary level between strategy and operations to investigate the relationship between the strategy formation process and business model innovation (Cortimiglia, Ghezzi, and Frank, 2016) as well as strategic decision-making in the business model innovation process (Reymen et al., 2017; Bigdeli et al., 2016).

A complementary, but smaller, stream of research explores the outcomes of business model innovation. For example, Anwar (2018) finds that business model innovation has a positive impact on the financial performance of SMEs, Kraus et al. (2017) explore the link between novel business model designs and the internationalization of firms, and Wei et al. (2014) consider the interplay of different types of technological innovation and business model design on firm growth. In the context of the biotechnology industry, Najmaei (2016) explores business model innovation as an intervening mechanism between process modularity and firm performance and finds that process modularity has a positive effect on a firm's pursuit of business model innovation, which in turn improves firm performance.

4. Discussion and future research

The process industries are characterized by a strong interlocking grip between production systems and products, complex transformation processes, where individual unit processes are either continuous or occur on a batch of materials (ingredients) that is indistinguishable, and interdependence across organizations and activities (Lager, 2010; Lager et al., 2015; Lager et al., 2017). These characteristics demand a close integration of production and innovation (Brown et al., 2005; Floyd, 2010; Frishammar et al., 2012; Frishammar et al., 2013; Samuelson and Lager, 2019), yet production and innovation management in process

industries are, in both theory and practice, often disconnected from each other (Hullova et al., 2016; Lager et al., 2014; Säfsten et al., 2014).

In this paper we proposed the business model – a system of interconnected and interdependent activities that determines how a firm creates, delivers, and captures value in concert with transaction partners (Zhao et al., 2020; Zott and Amit, 2010) – as a holistic and integrative concept that can bring research on innovation and production management in process industries closer together. Moreover, since the business model concept combines a product–market perspective with a process–manufacturing perspective, it may also facilitate cross-functional attitudes and behaviors in process-industrial firms. The purpose of this paper was, therefore, to capture the current state of research on business models in process industries, with a specific focus on innovation and production management, and to identify emerging themes that can serve as a basis for future cross-disciplinary research on the topic.

Our review of the literature on business models in process industries shows that the field has expanded over the past twenty years, but despite the growing scholarly interest in process-industrial business models, it is still in an early stage of development. The field displays many of the characteristics of an emerging and evolving theoretical idea that develops slowly, over long periods of time. Our reading shows, for example, that several process industry studies take the meaning of the business model (innovation) concept more or less for granted, not explicitly defining it at all. This gives rise to a number of different interpretations and, therefore, represent a potential source of ambiguity, misunderstanding, and overlap with established concepts and theories. The lack of construct clarity is arguably one of the biggest challenges in the literature on business models in process industries. Without properly defining and theoretically grounding the business model phenomenon, theory development is difficult, if not impossible. Since this lack of construct clarity hinders theory-building (and subsequent empirical testing), process industry scholars interested in the

study of business models are reminded to carefully define the concept and differentiate it conceptually and empirically from more established concepts and theories, such as competitive strategy.

Notwithstanding that the field is an early stage of development, our review revealed several characteristics of the architecture of activities through which firms in process industries create, deliver, and capture value that allow us to define what a process-industrial business model is.

First, scholars suggest that firms in process industries create value by building integrated production and innovation systems that reflect the configuration of the value chain. On the one hand, integrated production systems create efficient value chains that extend beyond single products (Dmitriev et al., 2014; Reim et al., 2015; Visnjic et al., 2016; Wei et al., 2017), for instance, when by-products of one production plant can be used as the starting materials of another. This has implications for raw material and energy consumption, emissions, pricing, and logistics costs (Agrawal and Bellos, 2015; Bolton and Hannon, 2016; Curtis and Khare, 2004; Stoughton and Votta, 2003). Process firms, thus, exploit synergies in their production systems that impact the cost structure of their business models. On the other hand, firms in process industries create value by leveraging technologies and innovations (especially process innovations and corresponding innovation capabilities) across products and segments, thereby promoting the identification of new applications and solutions (e.g., a chemical firm may leverage know-how to develop, manufacture, and employ catalysts for different applications) (e.g., Bower, 2003; Davis, 2008; Dougherty and Dunne, 2011; Sabatier et al., 2010; Willemstein et al., 2007; Visnjic et al., 2016, 2018). However, in process-industrial business models it is not the individual production and innovation processes that make the difference, but their relationship to one another. In other words, the way in which firms connect and align production and innovation activities is a unique source

of value creation in process-industrial business models. The close integration of production and innovation activities is hence a defining characteristic of how firms in process industries operate, and it allows firms to generate feedback loops that strengthen elements of their business model. Process-industrial business models create virtuous cycles between production and innovation activities that are self-reinforcing: making consistent choices about raw materials, product ranges, process technologies, and so on has consequences for innovation activities like process innovation, which, in turn, enable further (production and innovation) choices. This creates dynamics that expand value creation and value capture. While prior business model research has noted the importance of fit between the constituting elements of a business model more generally (e.g., Johnson et al., 2008; Zott and Amit, 2010), the creation of a unique and tightly coupled production and innovation system that allows firms to operate more effectively takes center stage in the design of process-industrial business models.

Second, research on business models in process industries emphasizes interdependence across firms and activities (e.g., Ahl et al., 2018; Bogers et al., 2016; Boons and Lüdeke-Freund, 2013; Oskam et al., 2013; Shomali and Pinkse, 2016). Although prior business model research has characterized business models as the design of a firm's boundary-spanning transactions (e.g., Zott and Amit, 2007), thereby capturing the idea of exchanges that go beyond the boundaries of a focal firm, the notion of interdependence identified in our review goes beyond this transactional viewpoint. The relationships among multiple firms that need to be formed in order for a focal value proposition to materialize is a defining aspect of process-industrial business models. In process industries, the symbiotic relationship between a focal firm and its suppliers, customers, and other partners characterizes not only of the focal firm's business model but also those of its partners. When external partners are closely integrated into value-creating activities, their role shifts from passive entities to more actively engaged

partners in a firm's production and innovation processes. A particularly close type of collaboration in process-industrial business models is value co-creation (Breuer and Lüdeke-Freund 2017; Chesbrough, 2007; Chiang and Trappey, 2007; de Vasconcelos Gomes et al. 2018; Frankenberger et al., 2014; Helfat and Raubitscheck, 2018; Kortmann and Piller, 2016; West and Bogers, 2014), where partners share responsibility for value creation (i.e., power and control over the firm's value creation process) and where there is a high degree of interaction between the firm and its partner (e.g., customer, supplier). Indeed, process-industrial business models are highly dependent on a small number of effective partnerships to blend and (re-)combine ingredients in complex processes. For example, connecting to production plants, infrastructure, and technologies of suppliers and complementors might reduce costs in a focal firm's business model and thus impact how it creates, delivers, and captures value (Kortmann and Piller, 2016).

Together, these findings allow us to define a process-industrial business model as *one in which a focal firm and its partners interdependently create, deliver, and capture value by integrating innovation and production activities to transform raw materials (ingredients) in a set of discontinuous processes.*

Our review of process industry-relevant publications further revealed a family of emerging themes and common ideas (see Table 3 for an overview). Innovation management research on the topic has begun to explore the relationship between new technologies and business models, studying, for example, the interplay of choices regarding the design of a business model and the underlying technologies as a key resource. A related theme can be identified in the production management literature, where scholars have taken a value chain perspective to study the relationship between the business model and another key resource: production systems. This points to a common interest by scholars from both domains to

explore how the resource configuration of a process firm impacts the design and choice of business models (and *vice versa*).

INSERT TABLE 3 HERE

Building on these perspectives, future research on what characterizes business models in process industries, i.e., research on the content of business models, could explore in more depth the relationship between the activity systems forming the business model and the underlying resource configuration of process firms. Such research can, for example, study how digitalization impacts the way firms in process industries orchestrate and connect the resources they utilize and the corresponding activity system through which they create, deliver, and capture value. Clarifying the relationship between activity system and resource configuration can also assist in further characterizing process-industrial business models. While we have noted several typologies for business models operated by firms in various process industries, a systematic empirical analysis, i.e., one beyond single firms, of business models in process industries is still rare.

Another line of future inquiry could focus on the complex interdependencies between activities to explore what activities in a business model are connected and, perhaps even more important, how and why they are connected. This can contribute to a better understanding of how business models in process industries function and assist the development of theory concerning business models. In fact, process industry scholars are in a unique position to make theoretical contributions to the wider literature on business models because interdependencies between (innovation and production) activities have long been recognized and studied, albeit from other perspectives (e.g., product/process innovation). Yet, as our review shows, current research on business models in process industries still is somewhat domain specific. Future research could, therefore, consider activities and their

interrelationships more holistically by moving beyond a focus on innovation- or production-related activities and consider both simultaneously as well as other activities relevant for value creation, delivery, and capture such as transaction mechanisms. Existing research on business models in process industries has also not yet connected to prior work on activity systems (Aggarwal and Siggelkow, 2011; Porter and Siggelkow, 2008; Siggelkow and Levinthal, 2003). Building on prior theorizing can help clarify the theoretical underpinnings of the business model concept. For example, future process-industrial research on business models could build on complexity theory (Albert et al., 2015; Anderson, 1999; Porter and Siggelkow, 2008) to analyze complex transformation processes. Another opportunity related to interconnected structures and practices in process firms concerns configurational approaches (Fiss, 2011; Gelhard, von Delft, and Gudergan, 2016; Greckhamer et al., 2018). While current thinking in the reviewed literature recognizes variations in business models in form of different business model types, the literature has not yet empirically explored how different *gestalts* of process-industrial business models lead to superior firm performance. To address this gap, future research could, for example, utilize set-theoretic approaches and consider business models as systematically interdependent configurations of elements like the customer value proposition.

Our review also reveals that both innovation and production management scholars have begun to explore the role of stakeholders such as customers, suppliers, and partners in business models of process firms. This stream of the literature thus recognizes that value creation, delivery, and capture go beyond the focal process firm. While innovation management research has focused more on the role of partners in a business model as co-creators of value, production management scholars have taken a system-level perspective to understand how different business models overlap and interact in an ecosystem, especially in sustainability studies. Both domains, thus, take slightly different perspectives but agree that

there is a need to go beyond a focal firm's boundaries to fully understand how value is created. Although such a (eco)systems-based perspective has been proposed by business model scholars (e.g., Lanzolla and Markides, 2020; Zott and Amit, 2010), a specific research theme on stakeholders has not been identified by prior business model reviews (e.g., Morris, Schindehutte, and Allen, 2005; Ritter and Lettl, 2018; Zott et al., 2011). This suggests that it is an area where the literature on business models in process industries has established a unique position – one it can leverage to make a contribution. Specifically, while research on stakeholders and business models is, with a few exceptions (e.g., Priem, Wenzel, and Koch, 2018; Snihur, Thomas, and Burgelman, 2018; von Delft et al., 2019), rare, our review shows that it is a common theme in process-industrial research. Building on this position, future empirical research on the topic could therefore explore how firms in process industries organize and manage a multilateral set of partners and external activities. This research could, for instance, consider how platform business models in the process industries, which bring together various players, create value, and it could study positions and relationships between the business models of the platform owner and complementors to the platform.

Another emerging theme concerns the process of developing business models, i.e., the question of how business models form in organizations (see Figure 2). Production management research has addressed this question in the context of circular economy business models and, for example, studied the corresponding reconfiguration of supply and value chains in process industries. Innovation management research, on the other hand, has explored how new business models emerge and how established business models change over time in response to shifts in technologies. Both perspectives share the idea that dynamic environments may require the creation of new business models, but the literature has not yet addressed how firms in process industries learn to design new business models (or change established ones) and decide which element to adopt and which not to adopt. While prior

research emphasizes that design processes pertaining to business models are learned over time from experience, surprisingly little is known about what is actually learned. Most studies in the literature we reviewed infer learning based on changes in outcomes such as business model innovation but overlook what was learned. Future research may therefore consider an unexplored link between the business model and heuristics and decision making: how do firms in process industries use simple rules to guide decision making for developing business models? This research can also explore how capabilities related to the development of a business model (such as experimentation) are built (i.e., the microfoundations) by studying the role of specific actors, such as entrepreneurial managers, in building these capabilities as well as the aggregation of knowledge and skills, for example in form of organizational routines. By clarifying the microfoundations of capabilities related to, for example, experimentation (Gudiksen, 2015; Markides and Oyon, 2010; O'Connor and Rice, 2013) or the identification and exploitation of opportunities for business model innovation (Brink and Holmén, 2009; Schoemaker et al., 2018; Zook and Allen, 2011), this stream of future research can elucidate how such capabilities come into being. As Teece (2018b, p. 40) notes, "the crafting, refinement, implementation, and transformation of business models are outputs of high-order (dynamic) capabilities", but how these capabilities form remains largely unexplored.

INSERT FIGURE 2 HERE

Finally, a third area of future inquiry concerns the context in which process-industrial business models evolve. Our review shows that scholars have identified different business model types in various process industries, but a systematic exploration of differences between business models across process industries has not yet been conducted. The recognition of differences between process industries is not new (e.g., Lager, 2010; Lager et al., 2017), but

has not yet been considered from a business model perspective. Future research on business models in process industries could, therefore, explore how specific process industry contexts influence a firm's business model design. Future research in this stream can also explore how different types of business models perform in various contexts and compare process-industrial business models with those operated in other manufacturing industries. This would, for example, allow to explore the heterogeneity of process industries (Lager, 2010) from a business model perspective.

In summary, we recommend future research to explore what business models firms employ to create, deliver, and capture value, how business models form, and how the environment in which a process company operates influences the design and choice of business models (see Figure 2). Advancing our understanding for the *content*, *process*, and *context* of business model design is important not least because entrepreneurs and managers in process industries need to deal with the entire "beast", rather than focusing on only one point of view.

Future research on business models in process industries also has the potential to contribute to the development of a more general business model theory. Theory concerning the business model concept is still in its infancy (as evident from the lack of construct clarity noted earlier). Moreover, the aim of business model research is ambitious: to understand how firms create, deliver, and capture value with customers, suppliers, and other partners. The topical domain of the business model concept is thus broad and necessarily complex. Given the complexity of the phenomena involved and the limited time this field of inquiry had to develop, it is not surprising that the business model is not yet a theory. How can process industry scholars with an interest in production and innovation management contribute to theory development concerning the business model?

In the previous paragraphs, we have outlined several topics for cross-disciplinary inquiry that emerged from our review of the literature. In this paragraph, we outline what forms such research could take. One approach is 'classic' theory-driven research, in which scholars test, extend, or build theory. Although the business model is far from being a theory, it has rich and clearly identifiable theoretical roots that can provide a ready platform for theory development, including the resource-based view, transaction cost economics (Amit and Zott, 2001; Zott and Amit, 2010), disruptive innovation (Christensen et al., 2015; Snihur et al., 2018), and organizational learning (Andries et al., 2013; von Delft et al., 2019). Yet, as noted, our review of the literature on business models in process industries shows that only a handful of scholars build on any of the theoretical foundations identified in prior business model research, leaving the resolution of conceptual issues and theory development to others. Our review also enabled us to identify connections to existing theories, such as complexity theory, that future research may hence want to consider. Indeed, theoretical foundations and connections to established theories can be a useful starting point for future research to further increase our understanding of the process, content and context of business models, and assist in the development of theory concerning business models. Our recommendation for scholarship on business models in process industries is, therefore, to embrace the theoretical roots of the business model concept for empirical testing as well as for further theory building through inductive research.

Process industries are also a rich setting for phenomenon-driven research, especially in regard to themes such as digitalization and circular economy. Phenomenon-driven-research is defined as "a problem-centered orientation to research, focused on capturing, documenting, and conceptualizing organizational and managerial phenomena of interest" (Schwarz and Stensaker, 2016, p. 245). Phenomenon-driven research may require a reasoning that proposes "speculative – but plausible – conjectures about the nature of a phenomenon, and hence what

kinds of evidence might increase the prospects of further insights into it" (Folger and Stein, 2017, p. 307). In contrast to theory-driven research, this mode is not based on established theories and theoretical perspectives but rather aims to surface and explain emergent phenomena that existing theories cannot adequately predict or explain. Such abductive research at the pre-theory stage typically starts with a surprising observation or an unexpected finding, which leads to the generation of plausible insights or "first suggestions" for their explanation (Harman, 1965; Locke, Golden-Biddle, and Feldman, 2008; Shapira, 2011; Thagard and Shelley, 1997). Scholars could for example use such an approach to generate plausible conjectures and first insights into the nature, antecedents, and consequences of business model design in process industries. Yet, such an approach is rarely used in the existing literature. However, questioning theoretical assumptions and foundations, or surfacing anomalies, seems – especially given the early stage of development – a promising route for future research on business models in process industries. What is more, we would argue that process industries are a rich source for surprising or unexpected results because they are, in relative terms, understudied and thus await the discovery of new business model phenomena.

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Figures and tables

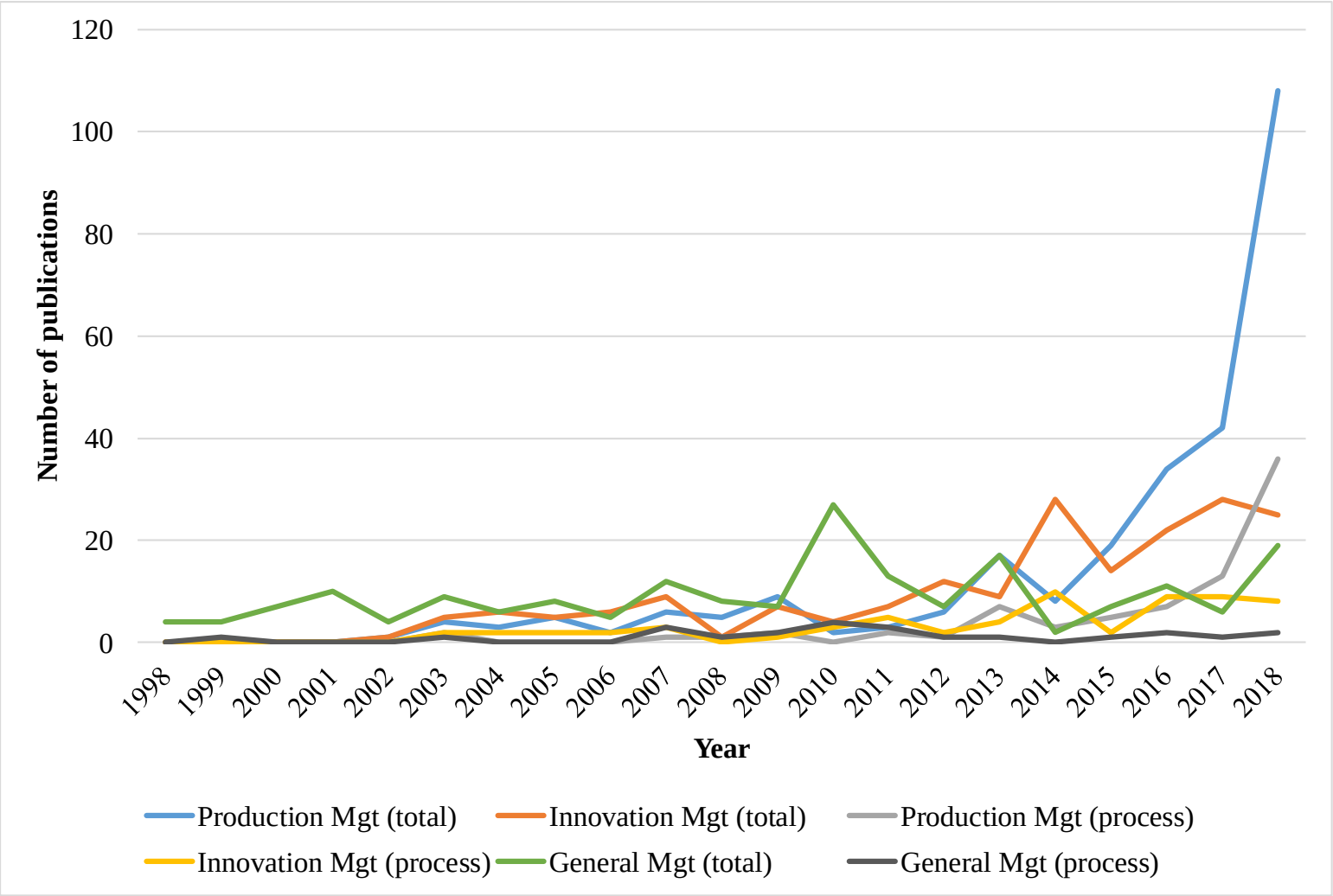

Figure 1. Business model articles in management journals.

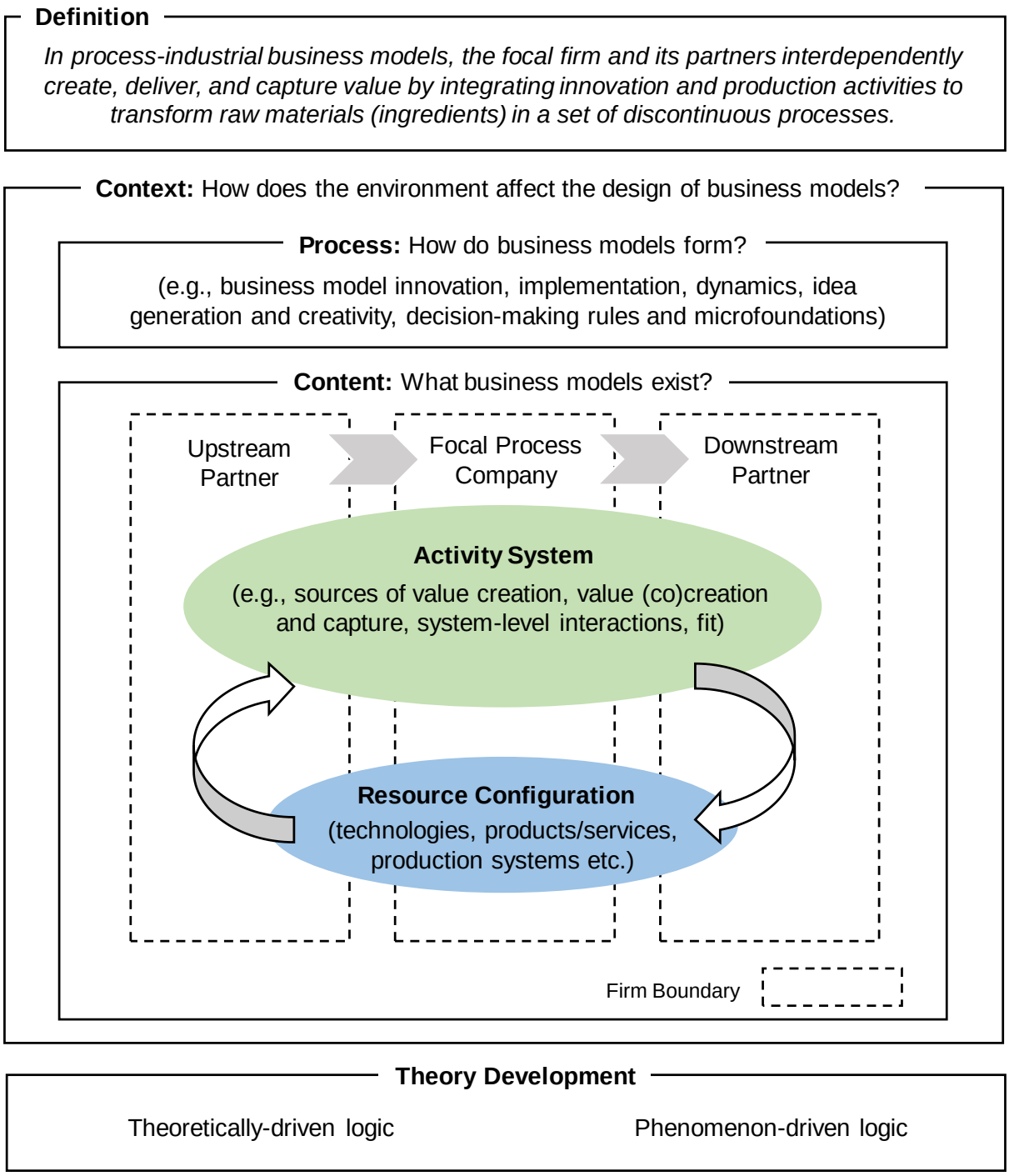

Figure 2. Research model for future research on business models in process industries.

Table 1. Overview of the sample.

Journal title	Number of articles on business models[1]	Number of business model articles relevant to process industries
Academy of Management Journal	3	1
Academy of Management Review	2	0
Administrative Science Quarterly	0	0
California Management Review	34	8
Creativity and Innovation Management	20	4
Harvard Business Review	54	5
IEEE Transactions on Engineering Management	6	0
International Journal of Operations and Production Management	15	4
International Journal of Production Economics	34	6
International Journal of Production Research	25	4
International Journal of Innovation Management	26	9
Journal of Cleaner Production	182	63
Journal of Management	2	0
Journal of Management Studies	1	0
Journal of Operations Management	4	1
Journal of Product Innovation Management	15	8
Long Range Planning	56	3
Management Science	9	1
MIT Sloan Management Review	18	4
Organization Science	6	1
Production and Operations Management	8	2
R&D Management	29	12
Research Policy	18	6
Strategic Management Journal	8	0
Technological Forecasting & Social Change	54	16
Technovation	30	9
Total	**659**	**167**

Table 2. Selected business model definitions in process industry studies.

Author (Year)	Definition
Spring and Araujo (2008)	"The business model is a framework that consists of the network structure, how transactions are made, how revenue models and incentives interact and how capabilities are accessed" (p. 444)
Boons et al. (2013)	"The business model concept provides a link between the individual firm and the larger production and consumption system in which it operates" (p. 1)
Iles and Martin (2013)	"A business model focuses attention on the core logic underlying how various activity systems in the company can fit together to deliver value to its customers and suppliers" (p. 39)
Matos and Silvestre (2013)	Business models describe the "way in which firms create value" (p. 62)
Bocken et al. (2014)	A business model "is nothing less than the organisational and financial 'architecture' of a business and includes implicit assumptions about customers, their needs, and the behaviour of revenues, costs and competitors" (p. 43)
Karlsson et al. (2017)	"The business model describes how a firm can be profitable by selling products and services" (p. 2926)
Kurucz et al. (2017)	The business model "captures the value creation rationale of a business organization, and therefore the *sine qua non* of any entrepreneurial activity" (p. 193)
Lagerstedt Wadin et al. (2017)	A business model "is a way to diffuse technologies" (p. 141)
Urbinati et al. (2017)	A business model "represents a set of strategic decisions that defines how companies create, transfer, and capture value according to their internal activities and relationships with stakeholders among which suppliers and customers" (p. 489)
Bini et al. (2018)	A business model is a "description of processes through which organizations implement their competitive strategies and create value" (p. 1161)
Geissdoerfer et al. (2018)	Business models are "simplified representations of the elements of a complex organizational system and the interrelation between these elements" (p. 713)

Borgh et al. (2012); Visnjic et al. (2014); Wei et al. (2014); Wei et al. (2017); Kamuriwo et al. (2017); Brehmer et al. (2018); Hahn et al. (2018); Olofsson et al. (2018); Oskam et al. (2018); Reficco et al. (2018); Ritala et al. (2018); Wei et al. (2017); Visnjic et al. (2018)	Based on activity system perspective developed by Amit and Zott (2001) and Zott and Amit (2010): A business model is "a system of interdependent activities that transcends the focal firm and spans its boundaries" (2010, p. 216)
Spector (2011); Bicen and Johnson (2015); Gudiksen (2015); Toro-Jarrín (2016); Joyce and Paquin (2016); Reymen et al. (2017); Kiel et al. (2017); Wainstein and Bumpus (2016); D'Souza et al. (2018)	Based on business model canvas developed by Osterwalder (2005) and Osterwalder and Pigneur (2010): a business model can be described by nine building blocks (value proposition, customer segments, distribution channels, customer relationships, key resources, key activities, key partnerships, revenue streams and cost structure)
Sabatier et al. (2012); Denicolai et al. (2014); Li and Garnsey (2014); Teece (2018)	Based on Teece (2010): "A business model articulates the logic, the data and other evidence that support a value proposition for the customer, and a viable structure of revenues and costs for the enterprise delivering that value" (p. 179).
Mustar et al. (2006); Willemstein et al. (2007); Bolton and Hannon (2016)	Based on Chesbrough and Rosenbloom (2002): "The business model is "the heuristic logic that connects technical potential with the realization of economic value" (p. 529).
Caila et al. (2007); Brink and Holmén (2009)	Based on Morris et al. (2005): A business model is a "concise representation of how an interrelated set of decision variables in the areas of venture strategy, architecture, and economics are addressed to create sustainable competitive advantage in defined markets" (p. 727).

Table 3. Overview of the literature on business models in process industries.

Domain	Purpose (why the business model concept is used)	Themes (selected studies: Author(s), Year)
Production and operations	• To explain the configuration of the value chain (what activities need to be performed to ensure the reliable and scalable delivery of value) • To offer typologies of business models in process industries (with a focus on how existing business models function) • To understand linkages between a focal process company and the larger production and consumption system (boundary-spanning set of activities)	• Types of business models and the configuration of production processes (e.g., Agrawal and Bellos, 2015; Chiang and Trappey 2007; Stoughton and Votta, 2003; Shomali and Pinkse, 2016; Wei et al., 2017) • Business models as market devices that connect a focal firm with stakeholders (e.g., Ahl et al., 2018; Boons et al., 2013; Kortmann and Piller, 2016; Oskam et al., 2018) • Business models and circular economy (Geissdoerfer et al., 2018; Veleva and Bodkin, 2018; Urbinati et al., 2017) • Business models and globalization of production networks (e.g., Brennan et al., 2015; Chiarvesio and Di Maria, 2009)
Innovation management and new technologies	• To understand how new technologies are commercialized through business models (what value creation and capture mechanisms are suitable to exploit new technologies) • To offer typologies of business models in process industries (with a focus on the technology – business model interface) • To explain how new technologies and business model innovations go hand in hand (why and how do new technologies create opportunities for business model innovation) • To understand the complexity and dynamics in introducing new business models and transforming established business models (how do new business models form, how do business models change over time, and what are the consequences of innovations in business models)	• Types of business models to commercialize technologies (e.g., Bigliardia et al., 2005; Mangematin et al., 2003) • Fit between technology and business model (e.g., Al-Aali and Teece, 2013; Bogers et al., 2016; Dmitriev et al., 2014; Kamuriwo et al. 2017; Kappor and Klueter, 2015; Lubik and Garnsey, 2016; Storm et al., 2013) • New mechanisms for value creation and capture through new business models (e.g., Phaal et al., 2011; Rao, 2017; Sabatier et al., 2012; Sorescu, 2017; Tierney et al., 2013) • Business model innovation process (e.g., Brink and Holmén, 2009; Dmitriev et al. 2014; Gudiksen, 2015; Markides and Oyon, 2010; O'Connor and Rice, 2013; Sinfield et al., 2012; Täuscher and Abdelkafi, 2017) • Business model innovation outcomes (e.g., Anwar, 2018; Kraus et al., 2017; Najmaei, 2016)

Appendices

Appendix 1. Search string.

Database: Scopus (available at: https://www.scopus.com/search/) **Search string:** (TITLE ("business model") OR ABS ("business model")) AND PUBYEAR > 1997 AND PUBYEAR < 2019 AND (LIMIT-TO (EXACTSRCTITLE, "Journal Name")) **Journal Name:** Academy of Management Journal, Academy of Management Review, Administrative Science Quarterly, California Management Review, Creativity and Innovation Management, Harvard Business Review, IEEE Transactions on Engineering Management, International Journal of Innovation Management, International Journal of Operations and Production Management, Journal of Management, Journal of Management Studies, Journal of Operations Management, Journal of Product Innovation Management, Management Science, MIT Sloan Management Review, Organization Science, Production and Operations Management, Research Policy, R&D Management, Strategic Management Journal Technological Forecasting and Social Change, Technovation

Appendix 2. Industry magazines used to confirm assessment of topic relevance.

Industry	Magazines
Chemicals	CHEManager, Chemistry & Industry
Food & beverages	Food and Drink Technology, Food Manufacture, New Food
Mining & metals	Metals and Mining Review, Mining Magazine
Pharmaceuticals	European Pharmaceutical Manufacturer, Pharma Manufacturing, PharmaTimes
Utilities	Energy Digital, Utility Week