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PREPARING FOR INDUSTRY 4.0: DIGITAL BUSINESS MODEL INNOVATION IN THE FOOD AND BEVERAGE INDUSTRY

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Abstract: The digitalisation of manufacturing will impact on all industries, including food and beverage: The so-called Industry 4.0 paradigm particularly denotes the exploitation and utilisation of real time data originating from an ubiquitous interconnection of objects, machines and humans (via the internet) across the entire value chain. Facilitated by an exponential growth in semiconductor and related digital capabilities, Industry 4.0 not only serves as a catalyst to improve processes or to design new product and service solutions. More fundamentally it is enabling entirely new business models which may not have been conceivable several years ago. F&b manufacturers face the challenge of both re-shaping their business model, at the same time as adapting their operations and products to this rapid socio-technological shift: This requires not only the customisation of the product service offerings of the business but also continuous adaptation and alignment of the firm’s value adding activities. However, today it is not clear, what manufacturing firms need to do to prepare for Industry 4.0 nor how to closely align Industry 4.0 initiatives with business model innovation. This paper shows by means of the first empirical investigation of UK-based food and beverage manufacturers that the application of Industry 4.0 activities is mostly tactical, and thereby decoupled from the firms’ business models. It argues that this stems from a lack of strategic envisioning on the impacts of Industry 4.0 on their entire businesses, and prevalent efficiency-oriented corporate cultures. Findings indicate that manufacturers should prioritise their I4.0 pathways early in the business strategy formulation process, in order to select the most appropriate technological solutions to enable these pathways. Whilst such prioritisation emphasises the importance to allocate resources appropriately, the dynamics of I4.0 require firms to *continuously* innovate their business model in order to implement I4.0. Thereby, two principle lines are key via the use of the three conceptual I4.0 pillars and the underpinning advanced mechatronics (1) to granularly segment customer needs and (2) to enhance the flexibility of value adding activities. These two approaches are mutually interdependent and hence an integrated approach through continuous business model innovation will enable manufacturers to be more responsive to individual customer needs; transforming their make-and-sell BM into sense-and-act BM. These results provide guidance for the application of Industry 4.0 in f&b manufacturing firms. This investigation is anticipated to be a starting point to develop an integrative framework to achieve consistency among business model components and achieve superior performance in light of (socio-) technological shifts for Industry 4.0.

Keywords: Industrie 4.0; Industry 4.0; Digital Manufacturing; Industrial Internet of Things; IIoT; 4IR; I4.0; Business Model; Business Model Innovation; Digital Business Model Innovation; Strategy; Tactics; FMCG; food and beverage

Preparing for Industry 4.0:

Digital Business Model Innovation in the Food and Beverage Industry

1. INTRODUCTION

Advanced information and communications technology (ICT) is on the brink of revolutionising the manufacturing industries, including fast-moving consumer goods (FMCG) industries such as food and beverages. As such a revolution is largely the result of the ubiquitous interconnection of things and humans via the Internet, many call it the Fourth Industrial Revolution. Large amounts of accessible real-time data through the interconnection of objects, devices and humans, powered by advanced mechatronics connected via the Internet, are central to the era of Industry 4.0 (**I4.0**). A widely accepted definition of mechatronics emphasises the synergetic integration of mechanical elements, electrical elements and intelligent computer control into a system (Auslander, 1996; Thramboulidis, 2008)[1]. Auslander (1996) emphasises the real-time decision-making capability of mechatronic systems by embedded software, as well as the general possibility to integrate not just mechanical systems, but many physical systems. These basic principles of Auslander's definition still apply today despite much progress in processing speed, capacity, construction size and the like. A significant advancement to mechatronics are systems that are uniquely identifiable via the internet and are thereby able to autonomously exchange information – these systems are today called 'cyber-physical-systems' or 'advanced mechatronics'[2] (Kagermann et al., 2013; Monostori et al., 2016), or from a business perspective sometimes also 'smart, connected products' (Porter & Heppelmann, 2014). As such, advanced mechatronics constitute the fundamental building block of I4.0, enabling real-time remote access to data about, and action on physical processes. More generally, also other modern manufacturing technologies may benefit from the application of advanced mechatronics, including unconventional material deformation process technologies, innovative material-removal processes or tool-less rapid manufacturing technologies (Koç & Özel, 2020). Research indicates that executives in many industries are seeking new ways to use digital advances to change customer relationships, internal processes and business models (Fitzgerald, 2012; Schneider, 2018; Statista, 2017). However, despite these signs of progression, manufacturing firms seem to have substantial problems understanding the idea of I4.0, and how to relate it to their specific domain (Burmeister, Lüttgens, & Piller, 2016; Müller, Buliga, & Voigt, 2018). Leaders in manufacturing firms exhibit strong ambiguity about their perception of I4.0; they view it as either a vision that should be accomplished, or a mission, meaning a way to achieve a certain business goal (ends versus means)

[1] An overview of definitions can be found here: https://mechatronics.colostate.edu/definitions/

[2] Advanced mechatronics and cyber-physical-systems are considered as synonyms for this article

(Erol, Schumacher and Sihn, 2016). As a consequence, enterprises are struggling to identify opportunities for strategic fields of action and to derive specific initiatives that support their move towards an I4.0 enterprise (Erol, Schumacher, & Sihn, 2016; Müller, Buliga, et al., 2018).

An exploratory study about the digital awareness of manufacturing firms operating in UK's food and beverage industry was conducted in order to obtain a better understanding of this 'digital ambiguity' among businesses. This article presents a survey and case studies of a group of companies in this industry and it is believed to be the first systematic inquiry into UK based food and beverage manufacturing firms' adoption of Industry 4.0 and its implications for business model innovation. This paper proposes that a holistic I4.0 implementation enables manufacturing firms to transform their BM from the traditional *'make-and-sell'* BM into a *'sense-and-act'* BM. Some critical aspects that manufacturing firms need to consider for this transformation will be highlighted, supported by a focus group study involving 20 firms operating in the UK's food and beverage market.

This paper contends that food and beverage manufacturing firms currently lack a strategically driven approach to I4.0. Moreover, it is posited that these firms are pursuing tactical approaches that are I4.0 solutions decoupled from the strategic agenda. In particular, the examined f&b firms use advanced mechatronic systems so far mostly to improve the efficiency of their existing business model by enhancing individual processes. One reason is that their business models have traditionally a focus on 'making and selling', i.e. producing products to then sell it to customers. Using a cultural value concept proposed by Hock, Clauss and Schulz (2016), several themes were identified that cause this disconnect between strategic vision and tactical action. In particular, the following three themes were identified – all three are characteristic of an efficiency-oriented organisational culture: (1) a focus on operational performance; (2) a lack of fluent communication and collaboration; and (3) an avoidance of risk-taking. It is shown that efficiency-oriented cultural values do not support systemic-based, continuous business model innovation in an organisation. In this paper it is argued that the prevalence of these cultural values within the examined firms is a root cause for taking on tactical approaches to I4.0, as opposed to holistic strategic approaches that are needed for continuous business model innovation.

Based on these insights, this paper revisits the relationship between the concepts of business strategy, business model contingencies and tactics of Casadesus-Masanell and Ricart (2010). The revisited concept focuses on an I4.0 environment to enable manufacturing firms to benefit from developments in advanced mechatronics and software interoperability alongside the shortened development time of I4.0 systems. In particular, this paper posits, that leaders in manufacturing should transform their organisational culture towards a novelty-centred culture that promotes continuous business model innovation. These steps should be complemented by the development of continuous business model innovation capabilities within the organisation, as the business model is regarded to be the central organisational logic for pursuing I4.0. Thereby, leaders in manufacturing firms should consider and prioritise the three pillars of I4.0 in the early stage of strategy formulation. Building on this, the paper further argues that the continuous innovation of the existing business model should have a two-folded I4.0-focus for utilising advanced mechatronics: (1) to granularly segment customer demands and (2) to enhance flexibility of value adding activities that are required to be more responsive to individual customer needs.

The expected reward for manufacturing firms that are embracing these two I4.0-foci and a continuous approach to BMI, is to transform their traditional make-and-sell BM into a sense-and-act BM. In contrast to merely improving the efficiency of their traditional business model "make and sell", where the fulfilment of expected customer needs are improved by the use of advanced mechatronics, this paper argues that manufacturing firms should transform their traditional "make-and-sell" BM into a "sense-and-act" BM. In the sense-act BM, manufacturing firms utilise especially advanced mechatronics to granularly *sense* real customer needs. Firms can then proactively *act* based on individual information about the customer to fulfil these customer needs. This BM archetype accounts for the shift towards individualised solutions that enable enhanced customer experiences and thus yield higher productivity and profits. 'Sense' thereby indicates the necessity and capability to closely understand either existing or potential customers with their individual needs based on granular information, about their applications, current and expected usage patterns and the like, mostly obtained through advanced mechatronics. Based on this information, customer needs can be granularly segmented into fulfillable demands. 'Act' refers to the manufacturer's ability to take advantage of these individual customer demands proactively. Flexibility thereby plays a vital role in several respects. First, indicating the capability to understand the required changes to the manufacturer's product and service mix in order to enable customers of existing and new products to better 'do their job', i.e. fulfil their customers' wishes. Second, flexibility denotes the ability to develop and produce these individualised products and services rapidly, and deliver them on time and on quality. Flexibility is significantly subject to effective access to data and flows of information to appropriately organise the flows of materials. Both of these requirements are made possible by the strategic use of advanced mechatronics, to obtain valuable information and take the required actions.

This study makes two major contributions. First, the study enriches the integration of I4.0 literature with the business model innovation literature by emphasizing how firms can create and deliver novel product-service offerings to customers effectively rather than merely improving the efficiency of delivering the existing product-service offerings. The paper shows the importance of an integrated view of strategy formulation, business model innovation and tactical execution in order to fully benefit from the adoption of advanced mechatronic technologies in the context of I4.0 initiatives.

Second, the study presents a framework that enables manufacturing firms to transform their BM from make-sell into sense-act, allowing them to make step-change improvements to their productivity and profit margins through the targeted fulfilment of customer needs. Given the opportunities and challenges manufacturing firms are facing with I4.0, these contributions offer a novel understanding of how manufacturing firms should seek to create and capture value with I4.0, and thereby expand existing knowledge from both theoretical and managerial perspectives.

2. LITERATURE

A wide exhaustion of traditional productivity levers leads manufacturing firms to invest significant resources in the development of digital advances to seek new ways to change customer relationships and enhance internal processes (Wee *et al.,* 2015, p. 11). This thinking was leveraged, in particular, by the speed in which digitalisation disrupted the media and retail industries within just one decade. The aftermath of these transformations has resulted in a shared notion among industrial and academic leaders that digitalisation applied to manufacturing 'will transform every link in the manufacturing value chain, from research and development, supply chain, and factory operations to marketing, sales, and service' (Hartmann, King and Narayanan, 2015, p. 1).

What is digitalisation

Digitalisation, however, is not a technical process but 'a sociotechnical process of applying digitized technology to broader social and institutional contexts that render digital technologies infrastructural' (Tilson, Lyytinen and Sørensen, 2010, p. 749). It can be operationalised as the transformation of processes, content or objects that used to be primarily physical or analogue into something that is primarily digital (Fichman, Dos Santos and Zheng, 2014). The revolutionary, wide-ranging character of this digital transformation originates from the properties of digital data, that (1) can be replicated with the same quality at zero marginal costs, and (2) can be communicated via the Internet in near-real-time across the globe (Brynjolfsson & McAfee, 2016; Iansiti & Lakhani, 2014). Digitalisation is predominantly subject to turning products or services into digital variants that offer advantages over their tangible counterparts (Henriette, Feki and Boughzala, 2015). Likewise, McFarlane (2017)[3] denotes digitalisation as 'the application of digital information [from multiple sources, formats, owners] for the enhancement of manufacturing products, processes, supply chains and services'.

Conceptualising Industry 4.0

As part of a new high-tech strategy for the German Federal Government, an initiative supporting the manufacturing industry with the developments subsumed under the umbrella of digitalisation was

[3]https://www.ifm.eng.cam.ac.uk/research/digital-manufacturing/what-is-digital-manufacturing/

founded and coined *Industry 4.0* (Kagermann, Lukas and Wahlster, 2011). Several authors suggest that I4.0, in particular, denotes the introduction of the Internet of Things and Services to the manufacturing industry, marking the beginning of a Fourth Industrial Revolution (Kagermann *et al.*, 2013, 2016; Spath *et al.*, 2013). Much like this definition, the US-based Industrial Internet Consortium [IIC] labels digitalisation in industry the *Industrial Internet of Things* and defines it as follows: 'An internet of things, machines, computers and people enabling intelligent industrial operations using advanced data analytics for transformational business outcomes' (The Industrial Internet Consortium 2015, p. 3). While the IIC promotes the use of digitalisation for industrial usage in general, the Industry 4.0 initiative focuses predominantly on the manufacturing industry, recognising in particular the need for a new approach and thinking about business models in manufacturing firms (Industrial Internet Consortium, 2015; Kagermann, Lukas and Wahlster, 2011; Kagermann *et al.*, 2013, 2016; Spath *et al.*, 2013; Bauernhansl *et al.*, 2016).

Neither digital technology nor digital information are particularly revolutionary to I4.0, as both have been around for several decades (Bauernhansl et al., 2016; Kagermann et al., 2013). However, synthesising publications that refer to these two initiatives and examine industrial applications, both are grounded on similar ideological principles that are based on the application of vastly progressing ICT technologies and infrastructures in manufacturing. Comparably new is the possibility to access in real time all the relevant information of a manufacturing value chain based on 'the networking of all the entities involved in the value creation process together with the ability to use this data to determine the optimal value stream at any given point in time' (Kagermann *et al.*, 2016, p. 5). Consequently, some distinct principles can be derived that underpin the transformative character of I4.0: (1) an ubiquitous origin of data regarding time, location, quantity and format, fuelled by advanced mechatronics and an Internet of Things, Data and Services (Kagermann *et al.*, 2013; Porter and Heppelmann, 2014); (2) Internet-based cloud technologies that enable the bulk storage of, and remote access to, these data (Kiel, Arnold, & Voigt, 2017; Porter & Heppelmann, 2014); and (3) significantly increased possibilities to exploit these large amounts of data using advanced analytics to convert them into valuable information and actions (Kiel, Arnold, Collisi, & Voigt, 2016; Müller, 2019).

Applying this thinking to the definition of manufacturing, for the purposes of this article, as 'the full cycle from understanding markets and technologies through product and process design to operations, distribution and related services' (University of Cambridge, 2015, p. 16; Brustolin and Jonker, 2012, p. 106), Industry 4.0 can be refined as follows:

> *Industry 4.0 can be defined as the exploitation of ubiquitous interoperability of the entire manufacturing value chain with the purpose*

of converting digital information into measurable action plans for sustained competitive advantage.

Operationalisation – the basic pillars of Industry 4.0

In order to bridge this overarching definition of the I4.0 paradigm with the enabling technologies, scholars suggest breaking down the paradigm into higher-order pillars (Bauernhansl et al., 2016). However, scholars have not fully agreed on what the basic pillars of I4.0 are. Table 1 summarises a selection of frequently used descriptions of the key pillars.

Table 1 Pillars of Industry 4.0 by different authors

Bauernhansl *et al.* (2016)	Wee *et al.*) (2015, p. 7):	VDI and ZVEI (2015)	Acatech (2013, p. 6)	Smart Factory Task Group of Industrial Internet Consortium (2017)
Vertical connectivity	Drive the next horizon of operational effectiveness	Vertical integration	Vertical integration and linked production systems	System-wide visibility
Horizontal connectivity	Adapt business models to capture shifting value pools	Horizontal integration	Horizontal integration	Global supply chain integration
Real-time optimisation	Build the foundations for digital transformation	End-to-end engineering	Digital consistency of engineering along the entire value chain	Industrial digital thread

Wee *et al.'s* (2015) three pillars might be well suited as an implementation recommendation in a firm; however, they provide limited value in terms of understanding and operationalising I4.0. Nevertheless, there is an obvious tendency to perceive two pillars as (1) vertical integration and (2) horizontal integration. Acatech (2013), and VDI and ZVEI (2015), similarly regard the third pillar as the consistency of engineering from one end of the value chain to the other, whereas Bauernhansl *et al.* (2016) consider the third dimension to be real-time optimisation.

Considering the overarching theme of I4.0, which is centred around access to, and exploitation of, real-time data, it is reasonable to consider real-time optimisation as generally inherent in I4.0 rather than being an additional pillar. Perceiving horizontal integration (value chain integration) as the third pillar of I4.0 acknowledges that the value chain is an integral part of a firm's business model (Demil & Lecocq, 2010; Velu, 2017). Generally, the integration and orchestration of all elements of a business model are seen to be crucial for achieving competitive advantage (Zott & Amit, 2010).

The following sections provide a brief description of each I4.0 pillar described above and depicted in summary form from the extant literature in Figure 1.

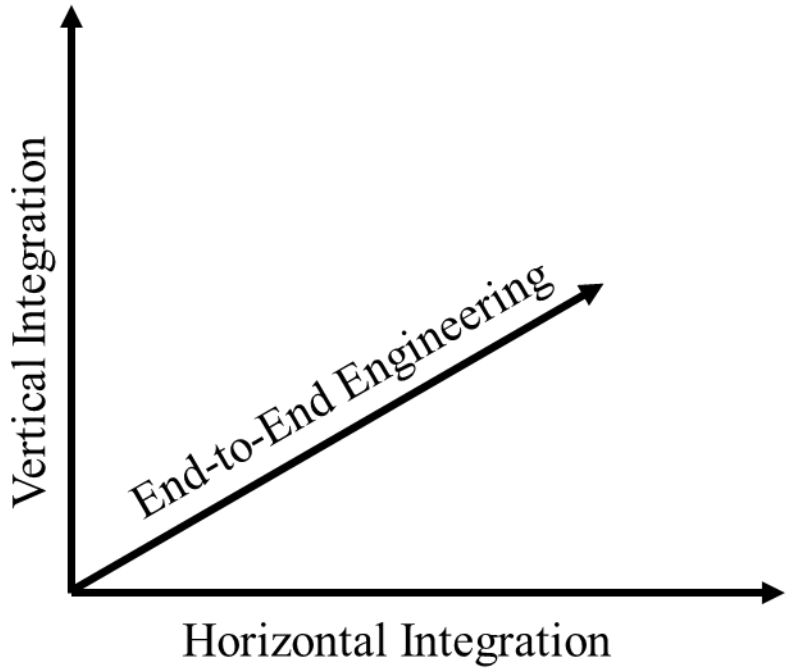

Figure 1: The three pillars of Industry 4.0

Vertical integration [VI]

Vertical integration has been pursued for several decades, and it denotes the intra-company integration of the means of production across all hierarchy levels of the business towards a cohesive system (Acatech, 2013; Schneider, 2018). These real-time interconnected systems are furthermore integrated with business processes to provide meaningful usage to the business (Acatech, 2013). The general thinking of vertical integration itself is neither new nor unique to the concept of I4.0. However, a new aspect of VI in I4.0 is the integration of information from things, most notably from products and work pieces, as they were not previously used to provide much data (Smart Factory Task Group of Industrial Internet Consortium, 2017). The VI in a firm is largely driven through advanced mechatronics, the Industrial Internet, as well as human–machine interfaces and data analytics coming closer to the shop floor (Acatech, 2013; VDI and ZVEI, 2015; McFarlane 2017).

Horizontal integration [HI]

Horizontal integration denotes the interconnection of all partners and processes within and beyond one factory's wall across the entire value chain, between which material, energy or information flow (Acatech, 2013; Schneider, 2018). A key enabler for HI is the use of the Internet of Things and Services in the entire value creation system (Bauernhansl et al., 2016). The consequence of this is a pursuit of HI that facilitates the dynamic creation of such added value networks (Acatech, 2013; VDI and ZVEI, 2015). The Smart Factory Task Group of Industrial Internet Consortium (2017, p. 5) adds that 'importantly, the systems that impact your Smart Factory will not all be internal. External systems from weather networks, suppliers, logistics partners, and technology providers share data with internal systems to drive insight and to coordinate action.'

End-to-end engineering [E2E]

End-to-end engineering is the capability to weave design, manufacturing, engineering and supply chain functions together, for capturing, exploiting and leveraging data both ways across the entire value chain for meaningful use (Smart Factory Task Group of Industrial Internet Consortium, 2017). This includes technical, administrative and commercial data. As these data are networked, they can flow and be used in inter-company networks, which results in a seamless convergence of the digital and the physical world (Erol *et al.*, 2016). Data from production can be used for maintenance services in the field, where information and insights are often lacking; in addition, maintenance data can be fed back to production or the design department for future product improvements (VDI & ZVEI, 2015). In particular, by exploiting these data with complex simulations of the real world, and using data from across the value chain, manufacturing firms can largely improve the overall efficiency of their manufacturing set-up and product quality, while reducing asset downtime during service (Smart Factory Task Group of Industrial Internet Consortium, 2017). Moreover, complexity costs are expected to significantly decrease through increased flexibility as a consequence of interoperable software systems across the value chain (Bauernhansl et al., 2016).

By considering vertical integration, horizontal integration and end-to-end-engineering to be basic pillars of I4.0, the entire manufacturing system is represented (Acatech, 2013) and could be considered a central component of the business model, as suggested by Demil and Lecocq (2010): the three I4.0 pillars represent the internal and external organisational system, accountable for creating and delivering a customer value proposition.

Benefits of Industry 4.0

Views about the benefits of I4.0 for manufacturing enterprises differ among authors. The benefits can possibly be synthesised into three main categories: (1) operational improvements; (2) commercial opportunities; and (3) depolarisation of strategic decisions.

Multiple scholars predict the benefits of I4.0 mainly to be delivered by the exploitation of data for *operational improvements*: by reducing the machine downtime by up to 45 per cent, increasing the production volume by 20–25 per cent (Wee *et al.*, 2015), reducing complexity costs by up to 70 per cent (Bauernhansl et al., 2016), or more generally through increased transparency and speed of decision-making based on real-time data (Müller & Däschle, 2018).

Moreover, consideration is given to the emergence of *commercial opportunities* with an anticipated revenue rise of 23 per cent (Hartmann, King and Narayanan, 2015). The main lever is expected to be provided by new product innovations with embedded sensors and actuators (Porter & Heppelmann, 2014). These smart connected products create possibilities for interaction with the product beyond its point-of-sale in the form of (individualised) services for customers that yield a superior productivity and profits for manufacturers (Burmeister et al., 2016; Engländer, Bleider, & Hoffmann, 2019; Schneider & Spieth, 2013; Weking, Stöcker, Kowalkiewicz, Böhm, & Krcmar, 2018). In general terms, it can be contended that the economy might shift from a product, and output-oriented, economy, towards an economy where an outcome is sold with specific deliverables, such as the specific up-time of equipment (World Economic Forum and Accenture, 2015; Kans and Ingwald, 2016; Martinez, Neely, Velu, Leinster-Evans and Bisessar, 2017).

A third category discusses a *depolarisation of strategic decisions* that reduces the traditional gap between two presumably contrary decisions. Through developments along the three main pillars of I4.0, it is expected to have adequate measures in place for technically and economically realising the formerly unimaginable manufacturing of a batch-size one product at competitive costs with reference to a mass-produced product (Burmeister et al., 2016; Kagermann et al., 2013). Moreover, the contradiction between differentiation and cost-leadership strategy is predicted to attenuate (Burmeister, Lüttgens and Piller, 2016; Engländer, Bleider and Hoffmann, 2019). Similarly, Ibarra, Ganzarain and Igartua (2018) advocate for I4.0 as a moderating mechanism between economies of scale by utilising low-wage countries, and increasing localisation of production, to serve the flexibility and speed of delivery that are required.

Business model perspective –- how to capture value from Industry 4.0

Beyond these three categories, the literature suggests that companies achieve better benefits from investments in I4.0 by taking a holistic approach which calls for the envisioning and execution of radically different ways of working (Schneider, 2018; Spath et al., 2013; Westerman, Calméjane, Bonnet, Ferraris, & McAfee, 2011). In contrast to the substitution or extension of individual assets or processes, pursuing a completely new way of working refers to mastering fundamental changes in a firm's business model: its components and their orchestration, from a different value proposition, and changes in the organisational systems to the resource and competence base (Wee *et al.*, 2015; Demil and Lecocq, 2010; Velu, 2017). Manufacturing firms have found this particularly challenging, as few holistic I4.0 best practices exist for reference purposes (Burmeister et al., 2016). Accordingly, I4.0 scholars argue that the modification of organisational structures and processes, as well as development of the necessary employee skills and qualifications, have been understudied (Erol, Schumacher, & Sihn, 2016; Spath et al., 2013).

Business models (BMs), possibly providing a fruitful lens to solve the holistic issue, are systems of interdependent activities that transcend the focal firm and span its boundaries (Velu, 2017; Zott & Amit, 2010). The BM as an activity system provides the architecture for a business to create value for customers and appropriate a share of this value in terms of profit by orchestrating the four main components of a BM, which can be summarised as the 4Vs (Velu, 2017): (V1) the *value proposition* that a business delivers to customers in the form of its products and services (Demil & Lecocq, 2010; Richardson, 2008); (V2) the *value creation and delivery* system, including the resources, capabilities and processes required to deliver the value proposition (Richardson, 2008; Teece, 2010; Zott, Amit, & Massa, 2011); (V3) the *value capture* mechanism that describes how value is appropriated (Richardson, 2008; Teece, 2010; Zott et al., 2011); and (V4) the *value network* of partners for the creation and delivery of value and for capturing shares of the value (Teece, 2010; Velu, 2017; Zott & Amit, 2010).

Baden-Fuller and Morgan (2010) perceive a business model as a cognitive model for managers to make decisions regarding their actions. Moreover, Tongur and Engwall (2014) argue that the business model as a cognitive concept provides fruitful insights into the challenges of an individual firm facing technology shifts. Although I4.0 can be seen as a technology shift, incumbent firms face cognitive challenges in identifying new business models, mainly because of the prevalence of the dominant design of the previous business model that made these firms successful (Kiel et al., 2017; Schneider, 2018). In their study on the impact of I4.0 on the individual components of a firm's business model, Kiel, Arnold and Voigt (2017, p. 15) point out that 'a long-term strategic vision and sustainable value creation, which is willing to take short-term losses' have to be pursued to exploit long-term and sustainable benefits from I4.0. However, their empirical study revealed only few examples of strategic I4.0 envisioning or business model thinking in manufacturing firms. Similar findings are reported by Arnold, Kiel and Voigt (2016), who observed few examples by manufacturing leaders to think about new revenue models, different distribution channels, new target customers or alternative sourcing models for a changing cost structure..

In addition, scholars from the I4.0 field articulate the need to adopt a business model perspective for research on I4.0, with a considerable consensus among the academic community (Thoben, Wiesner and Wuest, 2017; Smart Factory Task Group of Industrial Internet Consortium, 2017; OECD, 2017; Burmeister, Lüttgens and Piller, 2015).

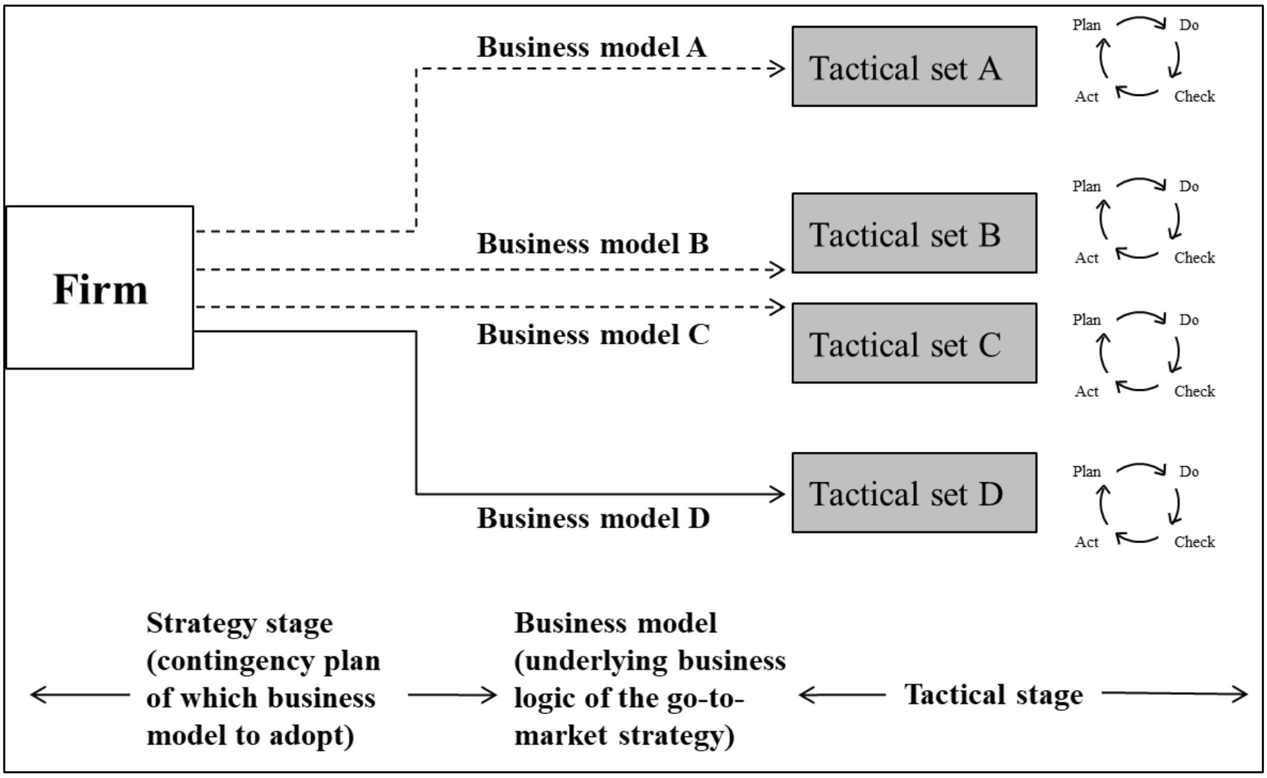

Figure 2: Relationship between strategy, business model and tactics (adapted from Casadesus-Masanell and Ricart (2010, p. 204))

A lack of strategic I4.0 envisioning and business model thinking among manufacturing firms points to the relationship between business strategy, business models and tactics, as proposed by Casadesus-Masanell and Ricart (2010) (see Figure 2). Empirical work on I4.0 business models remains largely silent on proposing ways to holistically approach I4.0 from a BM perspective in a manufacturing firm (Kiel et al., 2017; Müller, Buliga, et al., 2018; Müller, Kiel, & Voigt, 2018). The quest to examine I4.0 from a business model perspective accordingly denotes the necessity to follow a clear strategic envisioning about how sustainable value is created and captured from Industry 4.0 (Casadesus-Masanell & Ricart, 2010; Schneider, 2018). Teece (2017, p. 3) and adds that 'the various elements of a strategy must be aligned and coherent, and the same is true of the alignment between an organization's strategy and its business model'. If a firm is to capitalise on I4.0, this needs to be initiated by a dedicated business strategy, and executed with a clear focus on the firm's business model(s) as the central organising logic.

The business model as a strategic unit of analysis, advocated by Zott and Amit's (2010) notion to perceive the business model as an activity system, takes into account the interdependencies among individual sub-systems. From this arises the need to draw information and analyses about the individual sub-systems/BM components, as well as the firm's environment, from multiple sources, enabling 'more effective changing of the business model components while understanding the complex interdependencies to keep the system integrated with a view to keeping the revenue and cost architecture in continuous alignment' (Velu, 2017, p. 613). Here the notion to perceive a business model as a cognitive model is intertwined with the activity system perspective (Baden-Fuller & Morgan, 2010; Tongur & Engwall, 2014; Velu, 2017; Zott & Amit, 2010). This is particularly important for incumbent manufacturing firms while pursuing a shift from their traditional business model towards an I4.0-enabled business model, as the BM mediates between this technological I4.0 innovation and the firm's performance (Baden-Fuller & Haefliger, 2013). Developing and utilising the right I4.0 technology and pathway for the right BM element is therefore a matter of business model decision (Casadesus-Masanell and Ricart, 2010), driven by the firm's strategic vision and based on the managers' cognitive envisioning (Tongur and Engwall, 2014) and ability to flexibly reconfigure resources and capabilities (Achtenhagen, Melin, & Naldi, 2013; Doz & Kosonen, 2010).

As discussed earlier, the challenge of continuously re-thinking and realigning an incumbent business model is a cognitive one. Hock, Clauss and Schulz (2016) argue that cultural values are an important factor in enabling such business model innovation. In their empirical study, they examine the underlying organisational values of two business model design themes, novelty and efficiency, and link them to the firm's capabilities that foster business model innovation, namely, strategic sensitivity, collective commitment and resource fluidity, as proposed by Doz and Kosonen (2010). *Novelty-related cultural values* are characterised by a high degree of flexibility, adaptability and creativity, as well as external orientation, differentiation and sensing of new growth opportunities through new markets. These values jointly encourage innovativeness. *Efficiency-oriented cultural values*, on the other hand, are located on the contrary side of the cultural dimensions, with a stark focus on stability and consistency, as well as an internal orientation and the achievement of clearly stated goals, controlled by the surveillance of all transactions. These values encourage internal optimisation efforts, rather than innovativeness (Hock, Clauss and Schulz 2016).

This paper builds on this idea to explicate some procedural elements for business model innovation in the context of I4.0. Especially against the background that tactics determine how much value is captured for the firm; however, the scope of the tactics that can be used and their interdependencies result in particular from the strategic path and the resulting business models (Casadesus-Masanell & Ricart, 2010; Velu, 2017). This is particularly important for I4.0 as the systems within and beyond a firm's boundaries become increasingly integrated[4] (Kagermann et al., 2013).

[4] An increasing integration of information does not necessarily constitute increasing business integration; because of recent shifts towards value networks, manufacturers are disintegrating their business to focus on certain strengths, but increasing their integration of data and information.

3. APPROACH / METHODOLOGY

This paper is based on a qualitative case study within UK's food and beverage industry. The main objective of the study was to obtain an understanding of the approaches of food and beverage manufacturers to I4.0, and their readiness to pursue I4.0 initiatives.

This study was explorative in nature and the aim was to examine in practice the very early phases of a new socio-technological paradigm. Based on the findings of the case studies, a significant empirical phenomenon is presented that had been touched on in earlier research studies, but which has received few explanations so far. The study followed an inductive process, as it started off with the empirical phenomenon of an increasing I4.0 adaption in manufacturing organisations around the globe. Empirical patterns were observed and compared with existing literature on I4.0 and business models to identify new areas for further research (see Glaser and Strauss, 1967). The goal of this study was therefore to further advance the I4.0 paradigm from a strategy and business model stance.

3.1 Data collection

Multiple sources were used to gather data, enabling triangulation and facilitating checking validity and reliability from one source to another (Gibbs, 2012). Data sources included interviews as the main source of evidence, followed by observations during a two-day seminar, including a two-hour focus group on I4.0, as well as written documents, mainly from the Internet (Yin, 2014).

The interviews were conducted with managers and senior managers from six different food and beverage manufacturing firms (labelled A–F), and Table 2 (below) provides an overview of the firms.

Table 2 Overview of the interviewed manufacturing firms

	Annual revenue 2015 / 2016 [EUR]	Served markets	Main products
Firm A	8,000 m	Multinational	Beverages and food
Firm B	15,000 m	Multinational	Beverages
Firm C	4,000 m	European	Packaging
Firm D	200 m	Uni-national	Food
Firm E	100 m	Uni-national	Equipment
Firm F	1,000 m	Uni-national	Beverages

The respondents were mainly recruited a priori from the attendees of a two-day seminar on open innovation in the food and beverage industry, themed I4.0. The selection of interview partners in the respective organisations was based on their involvement in, and knowledge about, I4.0 attempts in their firm. All interviews lasted between 60 and 75 minutes and were audio-recorded. The interviews were semi-structured and followed written interview guidelines, which were distributed to the respondents via email in advance of the interview. The interview questions centred on two main areas: (1) what operational, financial and customer challenges companies faced and their current responses to these challenges; and (2) the firm's prospects for digitalisation in general and I4.0 in particular. The latter included questions about the firms' approach to industry 4.0 and the perceived benefits, hurdles and risks of implementing I4.0.

The interviews were followed by a two-hour focus group with 20 manufacturing firms from food and beverages, including five of the six interview partners.

3.2. Data analysis

During the interviews, notes were taken, and the main findings were transcribed into an interview notes database when the conversations were still fresh. To validate and discuss the results from the interviews and supporting written documents, preliminary findings were reported and discussed at a two-day seminar, at which multiple representatives of both the participating companies (including five of six interviewees) and other food and beverage manufacturing firms were present, totalling 20 food and beverage manufacturing firms. Observations during the two-day seminar were noted down and added to the research database. During the two-hour focus group in the course of the seminar, one researcher and one consultant led the focus group, while one researcher took notes.

4. RESULTS

4.1. Summary of firm's operational and customer challenges

This section presents a summary and a synthesis of the findings related to the perceived challenges of the interviewed firms regarding operational and customer challenges, as illustrated in Figure 3.

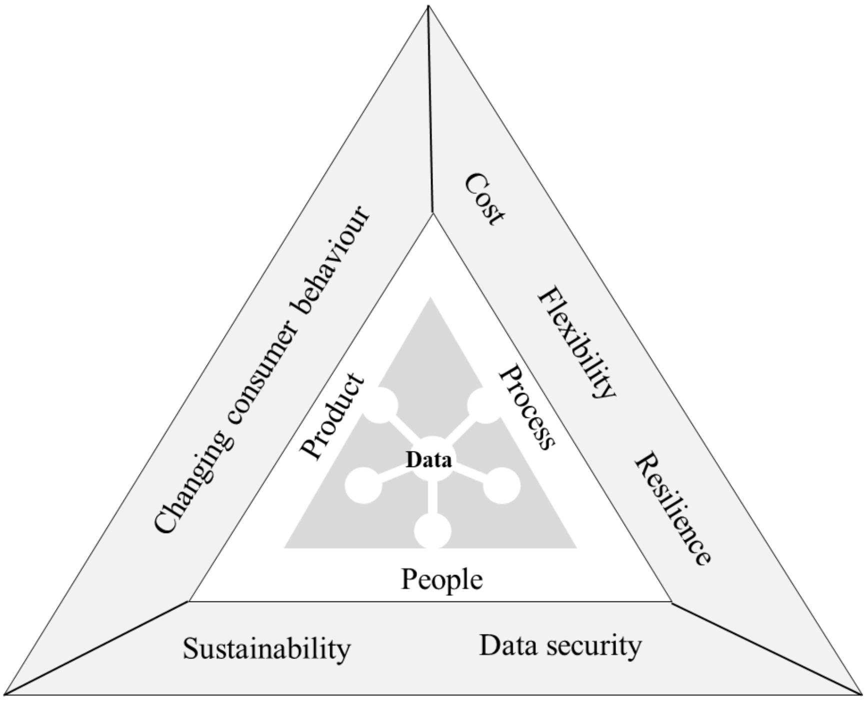

Figure 3: Synthesis of findings from interview study

Product challenges – Changing consumer behaviour

All six participating companies face the challenge of changing consumer behaviour towards healthier products with less salt, alcohol and fat, as well as smaller container sizes. As a consequence, the *'portfolio is changing due to an increasing customisation' (Company B),* for example, through locally brewed craft beer or locally sourced water. Resulting from this changing value proposition on the product side, the firms *'[...] are forced to become cheaper, quicker, and introduce new products' (Company F),* which means extensive challenges for their value chains.

Process challenges

In addition to increasing customisation, tough competition forces firms *'to balance flexibility and standardisation, and also provide service at proper costs' (Firm E)* to deliver a higher variety of products in smaller batches. These challenges match the findings from the literature, in which it is evident that fierce competition forces firms to exploit new ways to improve their productivity. Additionally, firms strive for higher resilience within their value chain in response to significant efforts to decrease waiting times and reduce costs out of the value chains: *'We must become more resilient, as the reduced stock and buffer levels increase the vulnerability of the value chain' (Firm D),* where small disruptions could influence large parts of the value chain and *'especially our promise to deliver fresh food on time every day' (Firm D).*

People challenges

The other two challenges depicted at the bottom of Figure 3 refer to the firm's view on I4.0. Sustainability here represents the viewpoint of the participants, that pursuing I4.0 features is mainly about a sustainable change of people's management. Hence, participants point out that *'Industry 4.0 without leveraging our people will not be successful' (Firm F),* which, when synthesised, may mean that I4.0 is equally about technical aspects and working on the organisation's mindsets. This is also one aspect related to 'data security'. On the one hand, interviewees were concerned about the privacy of their employees and their enterprise data; on the other hand, they stated that the organisation needs to think about the use of cloud computing and sharing data with its ecosystem in order to evolve.

Data

This consciousness about data security relates to the core challenge, as perceived by the participants, namely, data exploitation. It is considered risky, but at the same time the interviewees perceive the use of data to *possibly* yield high benefits for their firm. Moreover, the utilisation of data seemed to divide the participants, ranging from: (1) proactive approaches to thinking about data that could be beneficial to the firm, especially for a better understanding of customer demands (some examples from Companies B, C, E, F include: more detailed data from when a product is consumed, higher granularity of the value chain, the use of machine data for predictive maintenance); to (2) being in a state of uncertainty in terms of what action to take, such as Companies A and D, which found it difficult to create ideas about which data might yield interesting insights, and to make sense of specific scenarios in which the data might have value for the business.

4.2. Current Industry 4.0 initiatives to address operational or customer challenges

Figure 4 presents a summary of observed use cases and initiatives that solve operational or customer challenges in the examined businesses. The findings range from solutions without any degree of Industry 4.0 relationship to I4.0 solutions that exploit large amounts of real-time data. An example of a low degree of Industry 4.0 relationship was the establishment of an apprenticeship programme for training employees in Company C; however, the use of advanced mechatronics that may enable remote access to information and possibilities for remote action, is not subject to the training curriculum. A solution with a high degree of Industry 4.0 relationship, introduced by Company E, was the market introduction of a product-complementing software that enables real-time, cloud-based data monitoring and analysis of the product conditions.

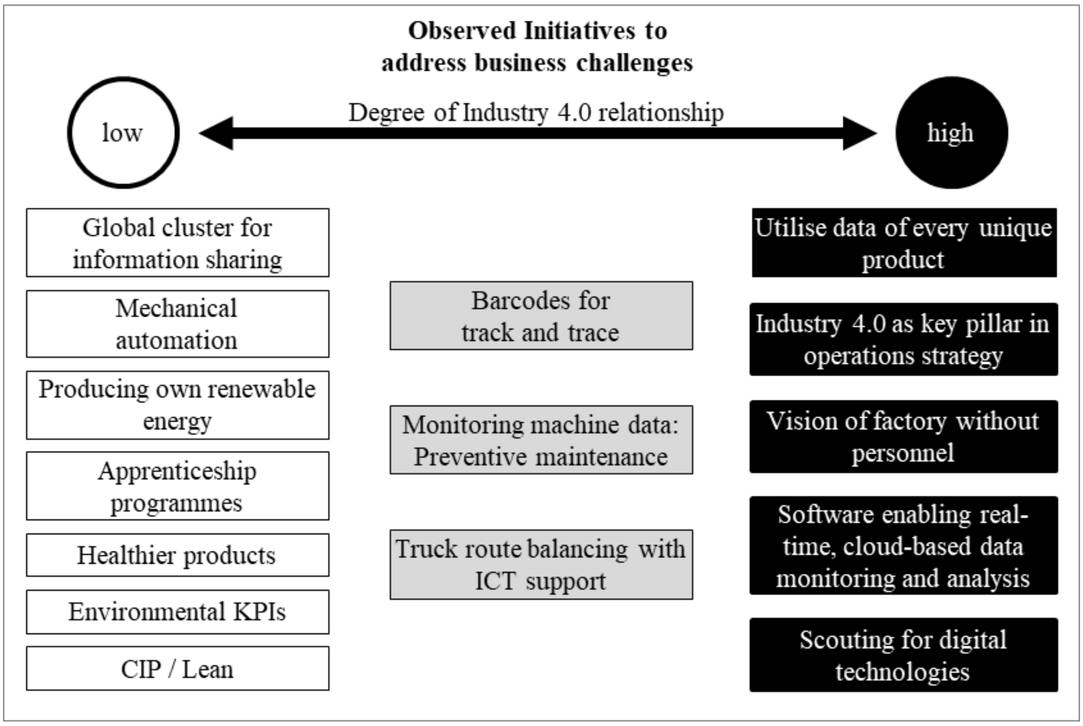

Figure 4: Overview of observed initiatives to address operational and customer challenges in case-study companies, grouped by degree of Industry 4.0 relationship

The findings further indicate that a holistic approach to Industry 4.0 was not the principal approach adopted by the examined businesses (see also Table 3). Only Company F exhibits attempts to implement I4.0 as part of the firm's operations strategy; one aspect thereby is the use of multiple advanced mechatronic systems that enable a factory without personnel, for example retrofitted devices that monitors the condition of production lines. Moreover, Company B and Company C have developed digitally enhanced products, holding potential for (not yet realised) new customer value propositions. Company B integrated advanced mechatronics into a beer tap that enables pub owners to more easily monitor the tapped quantity of beer, and at the same time sends consumption data and data about the beer condition back to Company B. Company C developed a uniquely identifiable product by means of fully unique QR codes for every single package. A QR code per se does not count as 'advanced mechatronics', however, these unique codes are developed to be identified by advanced mechatronic systems in retail stores that then send the corresponding environemtal conditions back to Company C. However, a holistic approach to I4.0, covering internal process improvements, as well as digitally enhanced product and service offerings, was not pursued by any respondent. Moreover, participants were mostly unsure about what a holistic approach might look like to effectively create and capture value for their customers using I4.0: Firm A, for example, noted that '*Industry 4.0 only costs money. Nobody was able to yet tell us, how we actually make money with it'*; likewise, Company B admitted that '*we haven't gotten specific business cases for Industry 4.0'*.

Table 3: Overview of Industry 4.0 activities and approaches of examined firms

		I4.0 use cases and activities, categorised by BM-component				General I4.0 approach	Management awareness about I4.0	Momentum to develop I4.0 forward
		I4.0 Value proposition	I4.0 Value creation	I4.0 Value capture	I4.0 Value network			
Firm	A	-	-	-	-	1 FTE to "think about I4.0"		
	B	.Pilot for digitally enhanced product	.Pilot to use I4.0 in operations to gather machine data	-	-	Thought- process started, whether I4.0 strategy should be developed		
	C	.Digitally enhanced product developed and tested, next step serial production	-	-	-	-		
	D	-	-	-	-	Exploring, what I4.0 is		
	E	.New software product to remotely gather data from equipment	-	-	-	-		
	F	.Digital consumer interaction piloted	.Piloting paperless quality .Piloting remote line control	-	-	.I4.0 as building block of new business strategy .I4.0 technology roadmap developed .Cross-functional I4.0 team in OPS established		

Legend:  Management awareness  Momentum to develop I4.0 forward

Note to Table 3: The battery load shows the perceived management awareness about Industry 4.0 and its potential. This is without taking into consideration what state might be desirable for each firm. The arrow indicates the perceived momentum within the firm to move forward with I4.0.

4.3. Hurdles and risks to pursuing Industry 4.0

Analysing and synthesising the hurdles and risks that prevent firms from pursuing I4.0 were inspired by the framework introduced earlier from Hock, Clauss and Schulz (2016), who propose a distinction between novelty-related and efficiency-oriented cultural values. Based on this framework, it is possible to examine whether the data provide evidence and an explanation for the restrained approach to I4.0 evident among the case-study participants: based on the data analysis, three themes were identified that provide an explanation for why I4.0 does not yet play an essential role in participants' organisations. Summarised in Table 4, these emerging themes can be explicated from efficiency-oriented cultural values: (1) a focus on operational performance; (2) a lack of fluent communication and collaboration; and (3) an aversion to risk-taking.

Focus on operational performance

A focus on performance was clearly present in four of the six interviewed firms. A similar tendency was also observed during the focus group activity. The case of Firm A provides a good impression of how other firms also tend to set their foci. Regarding the role and prioritisation of I4.0 in Firm A, it helps to understand that only one engineer within the entire global multi-billion organisation was appointed '*to see what we can do with Industry 4.0 in our organisation*'. Instead, the organisation had a clear focus on raising operational efficiency, as *'currently lean production is the language of our business [...] our firm is driven by performance'*. This focus on performance is also displayed in Firm A's approach to investment decisions in its European research and development centre. One manager, who was responsible for the strategic machinery and equipment developments, pointed out that strategic aspects, for example, regarding preparing a plant or equipment for the use of I4.0, were not considered, as '*payback is the basis for all investments*'. Comparable approaches were observed for other companies; for example, Firm F clearly stated that the '*focus [is] on continuous improvement and supply chain optimisation'*. Thereby, the operations team has started to investigate utilising individual I4.0 systems for enhancing efficiency within the supply chain, but purely focusing on cost-reduction measures, as Firm F's *'customer focus shifts towards cost'*, as opposed to new varieties just years before.

In summary, these examples present a picture in which organisations focus on continuous operational improvements with an explicit performance orientation. These policies can be clearly linked to efficiency-oriented cultural values that focus on internal improvement rather than encouraging innovativeness, which is necessary to capitalise on I4.0.

Lack of fluent communication and collaboration

A broad degree of scepticism was observed regarding individual organisations' abilities to communicate and collaborate efficiently. A senior manager in innovation management from a multinational food manufacturer pointed out during the focus group that his firm has *'even now problems to share information across the organisation, language-wise, but also the <u>willingness</u> to share information'*, which he sees as a large barrier that needs to be overcome in order to utilise I4.0. This was complemented by a product manager of a logistic provider for food and beverage firms who observed a need for *'well-designed processes beyond the brick walls of the warehouse'*. The latter observation of a supplier firm is clearly in line with the perception of one of the interviewed firm representatives, who reflects on his organisation as *'[...] lacking exchange of information within and across firm boundaries' (Interviewee Firm B)* or '*our organisation works in a matrix; however, departments tend to work rather isolated' (Interviewee Firm A).*

These case examples provide a behind-the-scenes view, where a lack of fluent communication and collaboration, both between departments and beyond the firm, points to strong silo thinking within departments, which is evidence of strong internal orientation. This internal orientation encourages individual solutions to problems, with little consideration given to what might impact other participants of the value chain. Needless to say, these cultural values do not foster an innovative approach to I4.0.

Aversion to risk-taking

A third theme emerging from the data is a tendency to avoid risk-taking. This might not generally be surprising for food and beverage firms, as taking a risk might have a direct impact on the public reputation of the firm – for example, securing food quality requires waterproof testing and quality procedures. Moreover, Firm B points out that stark competition among grocery stores worldwide resulted in ever-shorter supply cycles and buffer levels to decrease costs. To answer this challenge, Firm B has *'managed to build a very lean but resilient supply chain over the last couple of years; therefore, it is now difficult to serve the [changing] market requirements'*. This quote indicates the ambiguity faced by food and beverage manufacturers: to remain robust in current operations, but also to develop a higher degree of flexibility when answering consumer demands. Beyond this resilience, Firm F remarked that the organisation has to embark on a journey where *'not everything is going to be a success – we first have to learn to accept this kind of thinking'*. The same seems to be true for Firm A – while I4.0 might involve taking new pathways that could entail risk-taking to share data within partners via a cloud solution, Firm A's networks within the factories are entirely decoupled from any outside Internet access, thereby preventing any information-sharing because of security concerns. In short, he claims that *'IT is a blocker for us in pursuing Industry 4.0; we are always trying to be on the safe and cautious side'*.

This remarkable predisposition to avoid risk in several areas follows an attempt to achieve clearly stated goals and always being able to control all transactions. Comparing these observations to the cultural values' concept provides another indication of a somewhat efficiency-oriented culture.

Table 4: Selected quotes from interviews grouped into themes against the cultural value framework

Evidence from interviews, Jan–Mar 2017	Theme
A: 'Currently lean production is the language of our business' A: 'Our firm is driven by performance' A: 'A cultural problem in our firm is that we argue why we have not achieved the missing 2% rather than recognising the achieved 98%' A: 'Payback is the basis for all investments' B: 'The focus is on continuous improvement with root cause analyses' C: 'Cost reduction is a big topic' C: 'World-Class-Performance program' E: 'Focus on continuous improvement and supply chain optimisation' E: 'Customer focus shifts towards cost'	**Performance focus** *Focus on continuous operational improvement with explicit performance orientation*
A: 'Our organisation works in a matrix; however, departments tend to work rather isolated' B: 'We are lacking exchange of information within and across firm boundaries' C: 'Good exchange of information with an internal Open Innovation approach' F: 'The cooperation from our operations function with the IT department is very poor' F: 'Business model thinking is for the commercial team, not for us in operations'	**Lack of fluent communication and collaboration** *Strong silo thinking within departments*
A: 'IT is a blocker for us in pursuing Industry 4.0; we are always trying to be on the safe and cautious side' B: 'We have managed to get very resilient over the last couple of years, therefore, it is now difficult to serve the market requirements' F: 'We always have to justify all investments with a clear business case' F: 'Not everything is going to be a success – we first have to learn to accept this kind of thinking'	**Risk aversion** *Focus on control, stability and consistency*

Summarising the results of the collected case-study data, it can be postulated that there is generally a low level of maturity and readiness to pursue I4.0 across the studied firms. In summary, the manufacturing firms that were studied from the food and beverage industry are currently not well prepared for the utilisation of I4.0.

5. DISCUSSION AND CONCLUSION

The results indicate that the participating UK-based food and beverage firms largely lack holistic approaches to I4.0, and they are therefore not capitalising on the full benefits of I4.0. The observed I4.0 activities can exclusively be categorised as tactical changes within the given business model of the firm, as described by Casadesus-Masanell and Ricart (2010). Tactical I4.0 changes represent the improvement of the efficiency of individual, existing processes steps, e.g. by using advanced mechatronics or manufacturing automation technologies. However, the full potential of I4.0 originates from extensive and holistic interlinkage and interoperability of processes and actors across the value chain, spanning the focal firm to include suppliers and customers. By tactically using technologies for individual process steps, i.e. monitoring and prediction of machining parameters, or the simulation of surface qualities, manufacturing firms might let pass opportunities to revisit their business strategies and innovate the resulting business models to enhance flexibility and be more responsive to individual customer needs and hence contribute to higher productivity and profits.

This study shows, that I4.0 must be seen as a central element for future competitiveness as opposed to an emphasis on tactical improvements. Here findings build on an earlier study that suggests the management of technological shifts should consider the adoption of new technology to innovate both, the value adding activities as well as the product and service offerings at the same time (Tongur and Engwall, 2014). The simultaneous adoption of new technology to innovate the products and services as well as the value adding activities can be considered a holistic approach which is consistent and enhanced by the business model innovation perspective. Consequently, the consideration of sets of advanced mechatronics that enable and support I4.0-principles, will enable firms to change their business model holistically. This holistic consideration of innovation arising from I4.0 enables a firm (1) to organise their value adding activities both more efficiently and more flexibly, and thereby facilitate greater responsiveness towards changing customer needs. At the same time, tighter integration with customers and suppliers through software interoperability and advanced mechatronic such as in smart connected products and services, enables a firm to improve customer experience (2) through a more granular segmentation of the changing customer needs – a basic information input for responsive operations. I4.0 facilitates this two-folded innovation synchronism through deeper integration and interoperability of value adding activities and the product service offerings; these are largely interdependent, where changes in one activity or process affect (the relationship with) another activity or process (Velu, 2017).

To take an example, the full potential of using advanced mechatronics to monitor and predict a machine's maintenance procedures, only plays out when a firm uses these granular insights from the custom machine to innovate its BM. Firm E's initiative discussed earlier, for preventive maintenance with cloud-based data monitoring and analysis is an example of the focus of I4.0 initiative on improving the efficiency of the existing business model rather than on BMI. Similar example are frequently discussed in the literature – though, with less emphasis on the BM changes, cf. Benardos & Vosniakos (2017). Tailor-made product service offerings would enable the manufacturer to gain higher market shares by improving the experience of customers (and others with similar problem patterns) in a targeted manner; for example, through more reliable product quality, shorter lead times for spare parts, forward-looking recommendations for action.

The results of the cultural value analysis indicate that the examined food and beverage manufacturers have predominantly efficiency-oriented organisational cultures that do not foster the propensity to think about such business model innovation, as Hock, Clauss and Schulz (2016) demonstrate in their empirical study; on the other side, novelty-oriented cultural values show a positive effect on the propensity to business model innovation. The former is a problem for firms acting in the current I4.0 environment, as a propensity towards business model innovation is critical in order to fully capitalise on the benefits of I4.0 and thus the rapid progression of advanced mechatronics and software interoperability. This stems mainly from the dynamic change of customer demands and the shortening of cycle times of I4.0 systems (Kagermann et al., 2013), resulting in more frequent system changes, as depicted in Figure 5 (below).

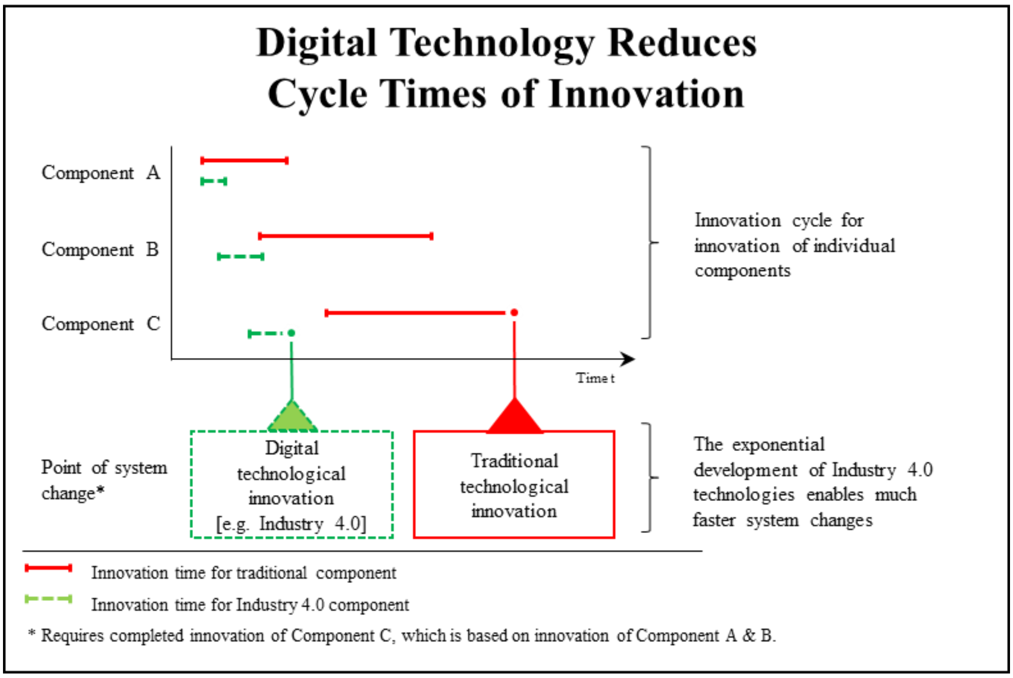

Figure 5 Comparison of development cycles for digital and non-digital system changes; adapted based on Kagermann *et al.* (2013)

Within the current I4.0 era, the exponential development of semi-conductor capabilities, enables faster technological developments in both hardware and software that generate large amounts of data to be utilised (Brynjolfsson & McAfee, 2016), particularly based on advanced mechatronics; in manufacturing (automation) and through their application in products and services. This enables much quicker and modular assemblies of different technological components to a working system (Schneider, 2018), in value adding activities and product service offerings alike. As indicated earlier, findings suggest blurring lines between value adding activities and the product service offerings, representing a convergence into a holistic system. Such a holistic system is best examined with a continuous business model innovation approach leading manufacturing firms to transform from their traditional make-and-sell BM towards a sense-and-act BM. This notion has several implications for further research on the intersection between advanced mechatronics, I4.0, business models and strategy, as well as for practitioners.

Implications for research

This study argues that the traditional set-up of continuous improvement in the tactical stage is not sufficient for the speed of the I4.0 era (see Figure 2 by use of the Plan, Do, Check, Act logic), referring to the usage of e.g. advanced mechatronics to improve an individual process step without an examination of synergetic effects. An alternative view is therefore presented in Figure 6, moving the continuous improvement one level upward, from the tactical stage to the business model stage – a continuous business model innovation. This approach factors in that a business model in the era of I4.0 may have to change quickly, as its activities are highly interdependent in order to be responsive to fulfil changing customer demands. Hence, changes and improvements need to be holistically monitored, controlled and managed from a system's viewpoint – the business model. A deep understanding is needed of the mechanisms that would enable continuous business model innovation towards an I4.0-supported sense-and-act BM. As a result of these accelerated and converged innovation cycles, scholars need to rethink the existing sequence and linearity of strategy development, the deduction of business model contingencies, and the testing and optimisation of tactical opportunities, as proposed by Casadesus-Masanell and Ricart (2010) (see Figure 2). This study contributes to such an understanding in three ways.

First, findings suggest a prioritisation of *utilisation focus* of I4.0 from the strategy formulation process onwards, ensuring a holistic but focused consideration of the various I4.0 facets that integrates the notions of (a) congruence among strategy and business models (Teece 2017), (b) the consistency within and among the business model components (Demil and Lecocq, 2010; Velu, 2017) and (c) the basic pillars of I4.0 (VDI & ZVEI, 2015). The holistic utilisation focus can be regarded as the choice of which of the three major I4.0 pillars predominantly enhances the business model. Thus, a BM with an emphasis on operational excellence may focus on vertical integration, supported by efforts in horizontal integration, whereas a BM with attention on individualised customer solutions may focus instead on end-to-end-engineering supported by some efforts in horizontal and vertical integration. Although the development paths in each pillar can be roughly distinguished, they are strongly intertwined. A utilisation focus accordingly does not mean that only one pillar should be chosen – it is about prioritising what pillar drives and controls the investments and innovations of I4.0 activities, which in turn highlights the starting points for the usage of advanced mechatronics.

This alternative view of the relationship between strategy, business models and tactics is based on the findings that manufacturing firms from the food and beverage industry are predominantly focusing on tactical changes that resonate from efficiency-oriented cultural values (see Table 4). Even despite changing customer needs, where consumers demand new products (cf. findings, where f&b firms experience demand for products with less alcohol, sugar and fat) in shorter cycles due to market pressure from start-up-like competitors, including micro-breweries. The prevalent efficiency-oriented cultural values include an aversion to risk and strong silo thinking within the firms' departments, resulting in tactical activities that are not suited to harnessing the potential of I4.0. However, as pointed out before, this paper argues that I4.0 develops its strength through a holistic approach from the strategy stage onwards.

Second, this paper therefore argues that a *continuous business model innovation process* is key to capitalising on I4.0. Contrarily to this study's findings, extant studies predominantly suggest technical solutions for individual problems in manufacturing processes to improve efficiency. Most manufacturing firms use BM frameworks that envision static BMI in the form of a one-off generation of new BMs. These frameworks do not consider the dynamic, ongoing changes in the interdependencies of activities in a BM; in particular between value adding activities, and the changing product and service offerings. However, due to the rapid technological developments, it is not enough for manufacturing firms to 'simply' develop new business models based on new mechatronic products, or to use advanced mechatronics to further optimise manufacturing operations as the end objective in itself. This paper shows that manufacturing firms must take an active process approach to innovate their existing make-and-sell business models on an ongoing basis towards a sense-and-act BM. This includes not only the usage of advanced mechatronics, such as in smart connected products, and advanced manufacturing automation, but foremost the active management of interdependencies of a closer integration and interoperability of the product service offerings and the value adding activity system. This continuous form of BMI is key for the successful implementation of I4.0, as the increasing interoperability and integration of systems in an I4.0 environment undoubtedly leads to an increasing interdependence of the impact of activities in the firm, that are subject to constant technological and customer-driven change.

To take an example from this study, beverage manufacturers face fierce competition from micro-breweries with individual and high-quality craft-beer recipes and demand for zero-alcohol beer. The beverage manufacturer Firm B, planned to react to these customer-driven changes by changing their product service offerings, by offering customers higher variety of products and entirely new product recipes. Facing these changes appropriately, however, requires them to increase the flexibility of their manufacturing operations as well as their entire supply chain due to smaller batch sizes, more changeovers, changing processing times and more diverse raw materials, presenting a big challenge for Firm B; especially as they traditionally have been bulk producing few types of beer to sell it globally. In contrast to larger firms such as Firm B, micro-breweries serve local, rather delimited markets, where they can quickly sense feedback from their customers about flavours, new recipes, alternative pubs to sell the beer and the like. This rapid and detailed information about customer needs enables micro-breweries to act swiftly, taking advantage of the arising opportunities sensed from their customers. Microbreweries have this responsiveness, by being able to quickly change their production set-up, their product recipes and the marketing of new flavours and thereby may act quickly on changing customer demands. Findings show that larger manufacturers also thrive for higher flexibility and responsiveness by utilizing advanced mechatronics, that for example allow automated, real-time tracking of their supply chains, further automated recipe changeovers or predictive equipment maintenance.

Hence, food and beverage firms are advised to granularly segment their current and future customer needs in order to quickly learn their customer's changing demands and serve their individual needs. To achieve this, a holistic consideration of I4.0 with advanced mechatronics and interoperable software suites play a key role. For example by supporting real-time access to purchase and consumption data from retailers and consumers alike, enabled through smart-product packaging or an increasing horizontal integration with retailers and other customers; i.e. taps in pubs that are equipped with advanced mechatronics to provide real-time data about beer consumption, temperature, CO2-content etc., as prototyped by Firm B in this study. These detailed data about beer consumption provide valuable insights about the consumption pattern of customers, especially in combination with other data sources, incl. weather or (local) sport events. This close integration across the value chain in combination with advanced mechatronics provide automated and more granular insights on product consumption and customer needs that in turn enable the manufacturer to granularly segment customer demands and based thereon take appropriate measures to increase responsiveness, i.e. rapidly fulfil these individual customer needs. Taken together, these developments denote a change in a manufacturers business model, from a traditional 'make-and-sell' BM into a 'sense-and-act' BM that takes advantage of changing customer demands, yielding higher productivity and profit.

In short, enabled by smart mechatronics and the principles of I4.0, manufacturing firms should thrive to granularly understand and segment their customers' needs, and building upon these increase the flexibility of their value adding activities to responsively serve these changing customer demands. As discussed, these activities have high synergetic effects that requires active management to harness through the continuous innovation of the existing business model.

Third, this study shows, that these holistic changes need to be accompanied by a cultural transformation that supports this flexibility, adaptability and external orientation. Viewing this process as a complex socio-technological system has implications for the development of a more comprehensive theoretical framework on how to effectively manage this business model innovation process within an I4.0 context.

With its increasing degree of integration and the business model as an analytical unit, I4.0 adds to Velu's (2017) idea of perceiving the business model as a complex organisational system. This paper contributes to this concept by highlighting cultural organisational values as a building block of this complex socio-technical system. In particular, certain cultural values influence a company's willingness to adopt an integrated and systemic approach to I4.0 and its business models. In addition, an initial idea for operationalising the interplay of this complex socio-technical system is proposed, as shown in Figure 6. Depending on the strategic focus, each pillar supports the development of certain elements of the company's business model. Vertical integration (VI) focuses mainly on value creation and delivery; while a mature horizontal integration (HI) can have a significant impact on value creation and capture, and changes in value propositions. Developments towards end-to-end engineering (E2E) are expected to have a significant impact on the value proposition and a significant impact on the value creation and delivery mechanism.

The shift from a 'make-and-sell' BM to a 'sense-and-act' BM requires systematic management of the costs and benefits. In particular, firms need to manage the alignment of the activities underlying the processes, the interrelationship between the activities and the governance in terms of decision-making rights as well as the rewards structure; both within the firm and across the network of firms. Such a process of managing the alignment dynamically requires leadership and the development of an appropriate people and skills strategy that matches the roadmap of the BM transition in order to fully realise the benefits whilst manging the costs and risks.

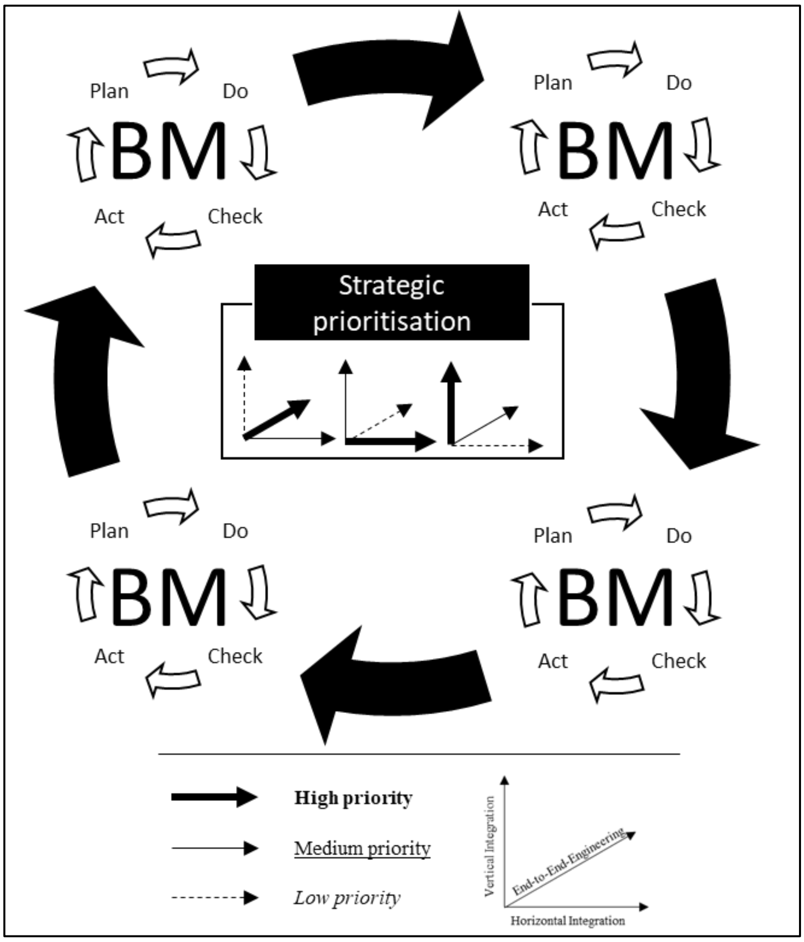

Figure 6: Proposed framework for relationship between Industry 4.0, strategy, business model and tactics

Implications for managers

This research highlights that manufacturing firms have to develop a dedicated business strategy entailing Industry 4.0 to prosper in the era of digital transformation. Moreover, management must scrutinise and revise their organisational culture – the efficiency-oriented cultural values that were predominantly prevalent in the studied firms (see Table 4) do not support a holistic utilisation of I4.0. If managers do not adopt a transformational approach to I4.0, they risk jeopardising I4.0 innovation before it even arises. Considering the proposed novelty-oriented values proposed by Hock, Clauss and Schulz (2016), it is suggested that leaders in manufacturing firms open their organisations to external partners and encourage a culture of creativity and entrepreneurship. The latter entails the empowerment of employees, with a strong focus on risk-taking, which is required to act quickly in order to take advantage of the shortened system development times for I4.0 systems.

A mutual interdependence with the cultural transformation is the strategic envisioning of I4.0 within the business strategy, which must be clearly communicated within the organisation – to get employees onboard with this journey and to dispel any concerns about digitalisation jeopardising jobs. Prioritising the three pillars of I4.0 must be complemented with dedicated instruments and incentives that support and foster the required cross-functional and cross-firm collaboration for the increasing integration of systems in this I4.0 environment. Moreover, leaders of manufacturing firms need to encompass within these activities an accompanied building up of competencies in business model thinking; the business model should act as the central element of a firm's capitalisation on I4.0. Tongur and Engwall's (2014) study about technology shifts and business models highlights the urgency of this approach, as many incumbent companies went out of business because they did not adapt their business models to the emerging competitive landscape.

Limitations and further research

Although this study has some limitations regarding its research design with a focus on the food and beverages industry, it identifies some key factors for achieving the implementation of I4.0 more generally across industries.

The academic community of business model and I4.0 scholars, and practitioners alike, would benefit from future work on an integrative framework to achieve consistency among business model components in order to provide guidance on how incumbent manufacturing firms manage the transition from their traditional business model to an I4.0-enhanced business model, both effectively and more efficiently. In support of this, academia and managers in manufacturing firms lack a detailed readiness model for the implementation of I4.0 across the business model – one that is based on existing theory and recognises the particularities of each I4.0 pillar. This study contributes to resolving this ambivalence by proposing a framework that encompasses the notion of I4.0 early on in the business strategy development; the framework especially asks/encourages, managers in manufacturing firms to engage in thinking about I4.0 holistically before they implement individual solutions. By considering which of the three I4.0 pillars should be prioritised, managers cognitively engage in envisioning, how each principle could change their existing business model. Only based thereon, technologies such as advanced mechatronics or software interoperability shall achieve this overarching business aim. By prioritising the I4.0 activities collectively and early in the strategy development process, managers can ensure appropriate resource allocation to rapidly implement changes that has a positive effect on the overall bottom line of the firm. The framework furthermore puts an emphasis on the prioritisation of the individual I4.0 pillars that influence the set-up of the firm's business model. In addition, consistency among the business model components can best be achieved by implementing a continuous improvement concept on the business model level. It is hoped that this study builds the starting point for further studies that expand scholarly understanding of this continuous I4.0 driven BMI by examining different industries with a wider selection of investigation methodologies. Multiple in-depth case studies that explore these continuous BMI approaches longitudinally are expected to yield great insights about the dynamics involved in this continuous BMI process.

Provided I4.0 is continuously accompanied by a BMI process, it holds potential to unlock the value of sets of advanced mechatronics that are utilised by I4.0. By embracing the framework presented in this study, manufacturing firms can manage to use technological developments around advanced mechatronics and wider I4.0 to transform their traditional make-and-sell BM into a sense-and-act BM that yields higher productivity and profits due to the targeted fulfilment of customer needs. The findings show that firms are advised to build capabilities in continuous BMI in order to strategically orchestrate the adoption of advanced technologies and actively manage the interdependencies across the activities both within and across firms in order to achieve mutual synergies. This approach of *continuous business model innovation* in the process of implementing I4.0 in food and beverage firms differs significantly from the prevailing notion in I4.0 literature to merely use advanced mechatronics for tactical improvements within an existing business model.

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