Archetypes for Industry 4.0 Business Model Innovations

Completed Research

Jörg Weking
Technical University of Munich
weking@in.tum.de

Maria Stöcker
Technical University of Munich
maria.stoecker@tum.de

Marek Kowalkiewicz
Queensland University of Technology
marek.kowalkiewicz@qut.edu.au

Markus Böhm
Technical University of Munich
markus.boehm@in.tum.de

Helmut Krcmar
Technical University of Munich
krcmar@in.tum.de

Abstract

Industry 4.0 (I4.0) also known as the fourth industrial revolution has emerged for describing the digitalization of manufacturing industries. In practice, the transition to I4.0 is crucial for manufacturing firms to sustain competitive advantage and seize new opportunities. Most research focuses on the technological aspects of I4.0 in form of product and process innovations. Despite I4.0’s rising attention among both researchers and practitioners, there exists only little research about I4.0 business model innovation (BMI), even though business model (BM) innovators can be more successful than product or process innovators. To address this research gap, we analyze 15 case studies of I4.0 BM innovators. We develop a taxonomy to characterize I4.0 BMs and derive 13 archetypes of I4.0 BMIs that describe transitions towards I4.0 BMs. The three identified super-archetypes are integration, servitization and expertise as a service. Our study deepens the understanding and structure of I4.0 BMs and I4.0 BMIs.

Keywords

Business model innovation, Industry 4.0, Industrie 4.0, Taxonomy, Archetypes, Case study.

Introduction

Gearing traditional industries towards the opportunities and challenges of digitization is frequently discussed among researchers and practitioners around the globe. Initiatives such as “Advanced Manufacturing Partnership” in the United States, “La Nouvelle France Industrielle” in France, “Future of Manufacturing” in the United Kingdom, “Made in China 2025” alongside the “Internet Plus” in China, and “Industry 4.0” in Germany address the convergence of “classic” industrial production with IT and new technologies, e.g. Internet of Things (Hermann et al. 2016; Liao et al. 2017; Ramsauer 2013). Innovating traditional industries is an indispensable prerequisite for securing competitiveness and economic wealth of the industrial nations in the long run (Ramsauer 2013).

Even though studies show that not only product and process but also business model innovations (BMI) are essential for future success (Wischmann et al. 2015), both researchers and practitioners mainly focus on the technological implications of Industry 4.0 (I4.0) (Burmeister et al. 2016; Demont and Paulus-Rohmer 2017; Kiel et al. 2016; Leyh et al. 2017; Leyh et al. 2016). Additionally, studies show that business model (BM) innovators are more successful than pure product or process innovators (Gassmann et al. 2013). Often, the provider with the best BM dominates the market and not providers of leading technological solutions (Chesbrough 2010).
Studies have recognized a lack of research about BMI in the context of I4.0. They address different aspects of it. Some authors investigate the BM components that are affected most by I4.0 (Arnold et al. 2016; Becker et al. 2017; Kiel et al. 2016). Others explore specific tools usable for I4.0 BMI (Burmeister et al. 2016). Some provide a specific process model to guide I4.0 BMI (Demont and Paulus-Rohmer 2017; Kaufmann 2015). However, these studies remain abstract and focus the transformation process. To the best of our knowledge, no study has analyzed case studies of I4.0 BM innovators to derive a taxonomy of I4.0 BMs or archetypes of I4.0 BMI. Though recent studies provide domain-specific taxonomies for superordinate concepts of I4.0, such as digital BMs (Bock and Wiener 2017; Remane et al. 2017b) or data-driven BMs (Hartmann et al. 2016), or for particular subtypes of I4.0, such as platform BMs (Täuscher and Laudien 2017), cloud BMs (Labes et al. 2013) or car sharing BMs (Remane et al. 2016). These taxonomies are either too general or too specific to classify I4.0 BMs.

Concluding, extant literature provides only little conceptual guidance regarding the questions: What characterizes Industry 3.0 (I3.0) and I4.0 BMs? How to classify I4.0 BMs? Which I4.0 BMI archetypes exist? These questions, however, are important for manufacturing firms to remain competitive and seize upcoming opportunities (Kiel et al. 2016; Ramsauer 2013).

In order to bridge gap, this article creates a taxonomy for I4.0 BMs and 13 I4.0 BMI archetypes. The remaining paper is structured as follows: In the next section, we outline the theoretical background about BMs, BMI and I4.0. Subsequently, we present a three-step research approach that consists of i) creating a case base of I4.0 BMI cases, ii) developing a taxonomy based on the identified cases and extant literature, and iii) empirically deriving I4.0 BMI archetypes by applying the taxonomy to the cases. Finally, we discuss our findings focusing on the strategic use of IT before we conclude our research.

**Theoretical Background**

Despite a large amount of research about BMs, no commonly accepted definition has been established so far (Foss and Saebi 2017; Schneider and Spieth 2013). Literature, however, converges on the components of BMs, although using different terminology. These components are value proposition, market segments, structure of the value chain, value capture mechanisms and “how these elements are linked together in an architecture” (Saebi et al. 2016). Most current definitions of a BM are similar or consistent with Teece (2010) definition (Foss and Saebi 2017): A BM is “the design or architecture of the value creation, delivery, and capture mechanisms it employs” (Teece 2010) and “how the enterprise creates and delivers value to customers, and then converts payments received to profits” (Teece 2010).

**BMI** represents a research stream of BM literature that recognizes the BM as a potential source of innovation next to product, service, process and organizational innovation (Foss and Saebi 2017; Zott et al. 2011). Despite rising attention for BMI in literature and practice (Schneider and Spieth 2013; Wirtz et al. 2016), research about the concept is still immature (Foss and Saebi 2017; Schneider and Spieth 2013; Spieth et al. 2014; Wirtz et al. 2016). BMIs “are designed, novel, nontrivial changes to the key elements of a firm’s business model and/or the architecture linking these elements” (Foss and Saebi 2017). So, “designed” implies that BMI is a deliberate process requiring top-management support. The claim for “novel, non-trivial changes” excludes minor adaptations of the existing BM, e.g. adding a new supplier.

The term “Industry 4.0” and the German version “Industrie 4.0” describe the digital transformation and a new manufacturing paradigm for traditional industries. The German government announced its eponymous high-tech initiative “Industrie 4.0” in 2011. However, there is no consensual definition about the term I4.0 and the dissociation of its predecessor I3.0 (Hermann et al. 2016; Pereira and Romero 2017). Literature does not agree if the term I4.0 denotes the transformation process or its outcome. Some authors define I4.0 as (i) the process “towards the increasing digitization and automation of manufacturing industry” (Brettel et al. 2014; Oesterreich and Teuteberg 2016), some as (ii) a new stage or paradigm for industrial production (Kagermann et al. 2013; Pereira and Romero 2017), i.e. the outcome of the process. Other authors use I4.0 as (iii) an umbrella term for new technologies and concepts (Hermann et al. 2016; Pfohl et al. 2015). We follow the outcome perspective and understand I4.0 as the fourth stage of industrial production. After steam power enabled mechanical production at the end of the 18th century (Industry 1.0), the intensive use of electrical power and assembly lines enabled mass production at the end of the 19th century (Industry 2.0). The use of IT and electronics enabled automated production at the second half of the 20th century (I3.0). Cyber-physical systems (CPS) and Internet of
Things (IoT) enable smart production nowadays (I4.0). CPS and IoT integrated in manufacturing enable smart processes, products, machines, systems and factories (Hermann et al. 2016). Elements can independently communicate and exchange information with each other, trigger and control the next actions, and steer the production (Pereira and Romero 2017; Ramsauer 2013). This results in a smart factory with "sensors, actors and autonomous systems" (Lasi et al. 2014). The factory can “context-aware assist people and machines in execution of their tasks” (Hermann et al. 2016) by drawing on information of the physical and virtual world. Additional key concepts of I4.0 are vertical and horizontal end-to-end integration. Horizontal integration combines resources, processes and IS intra- and inter-organizationally, across the entire value chain. Vertical integration refers to data sources within an organization (Kagermann et al. 2013).

**Methodology**

We divided our research approach in three sections. First, we searched for existing case studies about BMI in the context of I4.0 and set up a case base. Second, we developed a taxonomy of I4.0 BMs. Third, we derived I4.0 BMI archetypes of transitions from I3.0 to I4.0 BMs.

1) **Creating a case base**

We searched the scientific databases EBSCO, ScienceDirect, Scopus, IEEE Explore, and Web of Science for journals, books, conference papers and teaching cases, as well as Google Search for case studies about BMI in the context of I4.0. Moreover, we considered practice reports (e.g. McKinsey, BCG, Accenture, Microsoft), and case studies about the Industrial IoT and data driving BMI that fit to the I4.0 definition from above. If several authors mentioned a case, we combined it to avoid double counting and gain a more holistic case description. We got an initial set of 40 use cases. To augment case data and to support data triangulation (Yin 2014), we manually searched for the case studies’ BMs on the firm websites and publically available press releases. We gathered all information in a case base (Yin 2014). Finally, we checked all 40 initial cases for i) sufficient information of its BM and BMI, and ii) fit to the BMI definition from above. This resulted in 15 cases for further consideration: Ten cases explicitly labeled as I4.0 case and five cases mentioned in I4.0 related areas that meet the I4.0 definition (see Table 1).

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Firm</th>
<th>Main empirical study</th>
<th>Analyzed sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd Iteration: 10 cases explicitly labeled as I4.0 BMI</td>
<td>Atomic</td>
<td>Lassnig et al. (2017)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>AVL</td>
<td>Lassnig et al. (2017)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Claas – 365Farmnet</td>
<td>Bauerhansl et al. (2015)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>eMacheshop</td>
<td>Bauerhansl et al. (2015)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Kaeser Compressors</td>
<td>Kaufmann (2015)</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Konecranes</td>
<td>Wortmann et al. (2017)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Local Motors</td>
<td>Bauerhansl et al. (2015)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Shapeways</td>
<td>Bauerhansl et al. (2015)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>TRUMPF - AXOOM</td>
<td>Grünert and Sejdic (2017)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Zurnobel</td>
<td>Lassnig et al. (2017)</td>
<td>4</td>
</tr>
<tr>
<td>3rd Iteration: 5 cases from related topics fitting to the I4.0 definition</td>
<td>Adidas</td>
<td>Plattform-140 (2017)</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Caterpillar</td>
<td>Schaefer et al. (2017)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>GE Digital</td>
<td>Schaefer et al. (2017)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Ponoko</td>
<td>Gassmann et al. (2013)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Texa CARe</td>
<td>Microsoft (2017)</td>
<td>4</td>
</tr>
</tbody>
</table>

**Table 1. Case Studies**

2) **Developing a taxonomy**

We applied Nickerson et al. (2013) methodology to systematically develop a taxonomy for I4.0 BMs. The method allows us to combine theoretical findings of BMs with empirical findings of case studies (Remane et al. 2016). Following Nickerson et al. (2013), we applied a two-step approach.

First, we specified meta-characteristics that “serve as the basis for choice of characteristics in the taxonomy” (Nickerson et al. 2013) and the ending conditions for terminating the iterative approach. In accordance with Saebi et al. (2016), we chose the five generally accepted BM components *architecture, market segments, value proposition, value chain, and value capture* as meta-characteristics. Each dimension and characteristic of the taxonomy must relate to these characteristics. This helped us to systematically identify and organize relevant dimensions (Remane et al. 2016). We used the eight
objective and five subjective ending conditions suggested by Nickerson et al. (2013) following the research design of Bock and Wiener (2017).
Second, we developed the taxonomy with three main iterations. In the first iteration, we conducted a conceptual-to-empirical approach by deriving dimensions and characteristics from literature to base our taxonomy on extant research. In the second iteration, we proceeded empirical-to-conceptual by applying the taxonomy resulting from the first iteration to the ten explicitly labeled I4.0 cases. We randomly chose a case and conducted a qualitative structured data analysis (Miles et al. 2013). Further, we manually coded the case description by using BM patterns (Remane et al. 2017a) and empirically derived characteristics from the specific case (within-case analysis). Afterwards, we classified the case within the taxonomy, and, if necessary, added further characteristics and dimensions to the taxonomy until we analyzed all cases of our case base. We dropped and synthesized characteristics and dimensions to keep the taxonomy lean without losing discriminative power. The third iteration also followed the empirical-to-conceptual approach. We manually coded the description of the five I4.0 related cases by using BM patterns (Remane et al. 2017a) and empirically derived characteristics (Miles et al. 2013). We classified each case with the taxonomy resulting from the second iteration. Here, we did not have to add, merge or split dimensions or characteristics. Further, the taxonomy met all other objective and subjective ending conditions. Thus, we terminated the taxonomy development process.

3) Deriving archetypes

In order to derive BMI archetypes, we first applied our taxonomy to all cases in form of a within-case analysis (Yin 2014) to identify transition archetypes from I3.0 to I4.0 BMs, i.e. I4.0 BMIs. We characterized the initial BM (I3.0) and the new BM (I4.0) of each case using the taxonomy. The taxonomy reveals for each case the changes resulting from the case’s BMI. Second, we generalized from the case descriptions based on the taxonomy. We conducted a cross-case analysis (Yin 2014) in form of a qualitative cluster analysis. We identified three super-archetypes and ten related sub-archetypes with similar characteristics of the cases’ BMI.

Results

Taxonomy

The derived taxonomy for I4.0 BMI consists of six meta-dimensions and 23 dimensions with two to six distinct characteristics each. The meta-dimensions reflect the BM as defined above, namely the linking architecture that relates the BM components: target customer, value proposition, value creation and value capture. In order to improve the structure, we split the component value creation into two meta-dimensions: value chain and key elements. The meta-dimension architecture refers to a firm’s new BM. The remaining five meta-dimensions characterize both, I3.0 and I4.0 BMs. Table 2 shows the taxonomy.
**Archetypes**

We identified three super-archetypes and ten sub-archetypes of I4.0 BMs using the taxonomy. The super-archetype integration innovates its BM around new processes, servitization around new products, and expertise as a service around a hybrid of products and processes. Table 3 gives an overview.

<table>
<thead>
<tr>
<th>Super-archetypes</th>
<th>Sub-archetypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration</td>
<td>Crowdsourced innovation</td>
</tr>
<tr>
<td></td>
<td>Production as a service</td>
</tr>
<tr>
<td></td>
<td>Mass customization</td>
</tr>
<tr>
<td>Servitization</td>
<td>Life-long partnerships</td>
</tr>
<tr>
<td></td>
<td>Product as a service</td>
</tr>
<tr>
<td></td>
<td>Result as a service</td>
</tr>
<tr>
<td>Expertise as a service</td>
<td>Product-related consulting</td>
</tr>
<tr>
<td></td>
<td>Process-related consulting</td>
</tr>
<tr>
<td></td>
<td>Broker platforms</td>
</tr>
<tr>
<td></td>
<td>IoT platforms</td>
</tr>
</tbody>
</table>

**Integration – Process-focused BMI**

Integration covers BMIs starting from a value chain orchestrator to an integrator. An orchestrator is highly specialized on a single step of the value chain, whereas an integrator aims to cover the whole value chain (Remane et al. 2017a). The transition from I3.0 to I4.0 changes the meta-dimensions target customers and value chain. Concerning target customers, integration changes sales processes from indirect customer interaction via intermediaries (I3.0) to direct customer interaction via own online shops (I4.0). The direct online sales model complements the I3.0 solution or replaces it completely. Atomic, for example, sells ski via independent physical retail stores and its own online shop “customstudio”. In contrast, eMachineshop only uses its online shop. The value chain indicates most changes. Firms open their innovation processes by integrating customers and other externals in the product development. Smart production converts the production process from push to pull, and relocates factories from centralized production for a global market in low-wage countries to decentralized production close to the local markets even in high-wage countries. The super-archetype integration has three sub-archetypes: crowdfunded innovation, production as a service, and mass customization.

Crowd sourced innovation. A new product development and design process shapes this BMI. Firms move form a closed (I3.0) towards an open business model (I4.0). Using an innovation platform as a key resource enables them to integrate externals, individuals as well as businesses into product development. A community of people designs products (crowd sourcing) instead of only hired experts. The car manufacturer Local Motors, for example, announces challenges for car engineering on its innovation platform Launch Forth and members can hand in suggestions.

Production as a service. Transforming product ideas into physical goods is core to this sub-archetype. Firms of this type undertake the production from design checking until shipping for their customers. The value chain shifts from producing custom-made, expert designed goods (I3.0) to mass individualized, user-designed goods (I4.0). The customer becomes a key partner and can choose among a wide range of different materials and production techniques (long tail). The spin-off of Philips Electronics Shapeways.com, for example, is a platform for 3D-printed consumer goods. The firm offers a product printing service, an online shop and a designer community. Designers can upload their 3D design, select materials, and offer it to other members via the online shop. When receiving an order, Shapeways.com builds the product on-demand close to the final destination and ships it.

<table>
<thead>
<tr>
<th>Role in value chain</th>
<th>Orchestration</th>
<th>Integrator</th>
<th>Service &amp; support</th>
<th>Intermediary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key elements (how)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Key partners</td>
<td>Traditional within-sector partnerships</td>
<td>External individuals, businesses and research institutes (open BM)</td>
<td>Customer</td>
<td></td>
</tr>
<tr>
<td>Analytics as a key activity</td>
<td>No</td>
<td>Internal product and process data</td>
<td>Internal and customer's product and process data</td>
<td></td>
</tr>
<tr>
<td>Human role</td>
<td>Operating machines</td>
<td>Onsite maintenance</td>
<td>Remote monitoring &amp; maintenance</td>
<td>Software development &amp; IT</td>
</tr>
<tr>
<td>Platform</td>
<td>No</td>
<td>Closed</td>
<td>Trading</td>
<td>Innovation</td>
</tr>
<tr>
<td>Value capture (why)</td>
<td>Revenue model</td>
<td>Sales</td>
<td>Licensing</td>
<td>Revenue sharing</td>
</tr>
<tr>
<td>Contitunity</td>
<td>1x</td>
<td>Mixed</td>
<td>Continuous</td>
<td></td>
</tr>
<tr>
<td>Sales model</td>
<td>Ownership/service delivery</td>
<td>Use availability</td>
<td>Result</td>
<td></td>
</tr>
<tr>
<td>Profit logic</td>
<td>Reduce costs</td>
<td>Increase revenue</td>
<td>Both</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Taxonomy of Industry 4.0 Business Models

Table 3. Archetypes of Industry 4.0 Business Model Innovations
**Mass customization.** The integration of customers into the value chain characterizes this sub-archetype: a shift from mass production (I3.0) to mass customization (I4.0). Mass customization enables customers to adapt the final product to their individual taste by choosing among a range of options (long tail). Smart production enables economic production of small lot sizes, even lot size one. For example, Adidas’ customers can personalize shoes in the online-shop, i.e. change the color or add individual letters or logos.

**Servitization – Product-focused BMI**

Integrating sensors in products (digitally charged products) enables the super-archetype servitization to provide new product service systems instead of selling only tangible products. Thus, new offerings rather than new processes are the basis for this BMI, steering customers I3.0 production towards smart production. The meta-dimension value chain does not change. Architecture and target customers undergo different shifts per sub-archetype. New key resources are a closed IoT platform and analytics of product and process data from the customers’ sites. The human role evolves from an on-site maintainer (I3.0) into a remote observer and maintainer (I4.0). Long-ranging service contracts convert one-time sales (I3.0) into continuous revenue streams (e.g. subscription) and customer lock-in (I4.0). Predictive maintenance with more efficient service scheduling supports providers to reduce own costs.

Servitization includes offering complementary services to traditional product sales (life-long partnerships) and substituting product sales with services that include a product (product as a service and result as a service). The latter two sub-archetypes eliminate high investment costs for customers and, thus, address new customer segments. The sub-archetypes are an implementation of product service systems types according to Tikker (2004), Reim et al. (2015) and Weking et al. (2018) in the I4.0 context.

**Life-long partnerships.** IoT connected products enable this archetype to evolve its service portfolio from repair after failure and maintenance (I3.0) to prevent failures with remote monitoring and predictive maintenance throughout the whole product life cycle (I4.0). The firm becomes a solution provider with integrated product service solutions and a partner for customers for the entire product use phase. Before (I3.0) as well as after the BMI (I4.0), a firm generates significant parts of turnover by selling tangible products and transferring their ownership rights to customers. In I4.0, firms add continuous revenue streams with subscription-based, lifelong service contracts (I4.0). AVL List, for example, is a leading provider for tailored powertrain development and test system solutions. The firm offers remote usage and condition monitoring in addition to product sales. AVL aims to optimize product lifetime. They proactively exchange weak parts to avoid breakdowns.

**Product as a service.** Renting products (I4.0) instead of selling products and related services (I3.0) shapes this sub-archetype. Customers do not pay for ownership or service delivery (I3.0) but for use and availability of the product (I4.0). It provides new customer value by guaranteeing the products availability. Konecranes, for example, does not only sell industrial cranes (I3.0), but also rents them out based on a monthly fee (I4.0).

**Result as a service.** Selling the output or result of the product characterizes result as a service. This also enables continuous revenues streams. The sub-archetype allows for full-service packages and takes responsibility for safe operations and compliance. Kaeser, for example, innovates from selling compressors (I3.0) to selling compressed air per cubic-meter (I4.0). Kaeser takes full responsibility and operates compressors at the customer’s site.

**Expertise as a service – Hybrid BMI**

The super-archetype uses internally-build expertise of products or processes and offers it as a new consulting service (sub-archetypes product related and process related consulting) or a new product (sub-archetypes broker platform and IoT platform) to external customers (make more of it). The consulting sub-archetypes shift the value chain focus on service and support. They require the human role of consultants as key resources. Both transform the meta-dimensions value proposition and architecture. Value capture and value chain remain unchanged, i.e. one-time sales of new services in addition to traditional products manufacturing and sales (I3.0). The platform BMs offer a new platform-based, digital product together with complementary IT services. This shifts the firm’s role in the value chain to an intermediary and creates a multi-sided market. The BM addresses at least two independent customer
groups. The meta-dimension value capture moves from one-time sales to continuous subscription fees from different user groups, e.g. commissions from third parties (revenue sharing).

**Product related consulting.** The product related consulting complements product sales (I3.0) with advice and consulting (Tukker 2004) based on own experiences with the products. Firms provide new value to existing customer segments by offering integrated product service solutions (solution provider). This transition changes the meta-dimension architecture (product/service line extension and evolution of existing BM). Kaeser, for example, makes use of its know-how about its compressors by offering tailored system planning and energy saving consulting. They help customers to make optimal use of the product. In contrast, servitization archetypes cover repair, maintenance or operating services and not consulting.

**Process related consulting.** The process related consulting builds on experiences of internal processes. Firms offer this know-how as an advice and consultancy (Tukker 2004) to externals. This new service does not involve a tangible product. It addresses existing as well as new customer segments by approaching with a new value proposition, e.g. consulting about smart production and digital transformation. Compared to product related consulting, the meta-dimension architecture changes more radical. Here, the BMI is new for the company and may result in a company spin-off. TRUMPF, for example, a pioneer within I4.0, offers its internally gained know-how about its transformation from I3.0 to I4.0 as consulting service with its spin-off AXOOM.

**Broker platforms.** The archetype broker platforms describes how firms use experience from existing manufacturing and selling asset-intensive machinery (I3.0) and turn it into new digital products (I4.0). In our case studies, the new product is a cloud based platform for trading goods and services among user groups. Claas, for example, extends its manufacturing and selling farm machinery (I3.0) by offering a cloud-based software solution for farm management with its spin-off 365Farmnet. Thus, they use the IoT data from tractors and address further pain points of their customers, such as farm management, crop planning and paper work. TRUMPF, as a second example, manufactures and sells machine tools (I3.0) and additionally operates a trading platform for process parameters of their machine tools (I4.0). They help customers to adapt process parameters to new materials or production routings more efficiently.

**IoT platforms.** This sub-archetype makes use of experience on internal processes and smart production and transforms it into a new product. In our cases, the new product is an IoT platform. This is the basis for communities that can develop and sell complementary products. In contrast to the BM broker platform, analytics are key activities for this BM. The GE Software Center, for example, developed the IoT platform Predix as an internal solution for machine operators and maintenance engineers. They aimed to reduce GE machine downtimes and to schedule maintenance checks more economically (Schaefer et al. 2017; Winnig 2016). However, they started to offer customers an industrial IoT platform. They used their knowledge of their own analytics platform to extend their product portfolio due to market demand.

**Discussion and Conclusion**

In this study, we address the lack of research about I4.0 and related BMs and BMIs. Current research only analyzes I4.0 regarding technological and regulatory aspects. Based on 15 case studies, we create a taxonomy of I4.0 BMs for characterizing and structuring BMs and derive 13 archetypes of I4.0 BMIs capturing their transition from I3.0 BMs to I4.0 BMs.

Our study has two main implications for research. First, the taxonomy of I4.0 BMs and archetypes of I4.0 BMIs show how manufacturing firms use digital technologies to expand their competitive advantage. **Integration** cases mainly build on new online channels, i.e. online shops and innovation platforms, and digital manufacturing. Covering more parts of the value chain replaces intermediaries and enables faster reaction to changing customer demands. Firms integrate customers and other externals in product design and development. Customization options in online shops enable individualized products at competitive prices to mass products. New digital manufacturing techniques, such as 3D printing, reduce the labor intensity and allow production close to the market. The direct digital-to-physical transfer allows adaption to changing market requirements and a shorter time to market. **Servitization** cases especially use CPSS, IoT and analytics. IT-enabled remote product monitoring and predictive maintenance services reduce downtime of the customer’s plant and help customers to reduce costs. Customer contact extends to the whole product lifecycle. Providers generate continuous revenue streams due to multi-year contracts and increase the customers’ switching costs. Additionally, remote monitoring and predictive maintenance help
providers to reduce their own service costs with more efficient scheduling of service teams and maintenance visits. Real-time monitoring makes rental more attractive and enables usage-based revenue models. Expertise as a service cases strategically use IT to offer new, complementary goods and services. In our cases, new products are or emerge from IoT platforms, digital trading platforms, or two-sided market platforms for business applications. These products also enable new, digital processes. Further, providers use their expertise of digital products and processes to consult customers. Overall, the results show how the combination of new technologies and BMs lead to competitive advantage, which remains a challenge in research (Chesbrough 2010). Second, the taxonomy of I4.0 BMs reveals how digital technologies support specific BM components (Saebi et al. 2016). Digital technologies enable continuous, usage-based revenue models as part of the value capture component. Manufacturing firms use platforms and new forms of analytics as new key elements. Firms can address new customer segments online and directly. Digital products and services change the value proposition component. Digital technologies may transform the value chain towards decentralized, individualized and on-demand production. They support the vertical and horizontal end-to-end integration of the value chain. Hence, the taxonomy and archetypes reveal that all BM components may change in I4.0, in contrast to its initial understanding that mostly the value proposition, core competencies and relationships change (Arnold et al. 2016).

For practice, this paper shows how to use or build upon I4.0 including smart manufacturing, CPS and IoT. Practitioners can use our taxonomy to assess the I4.0 readiness of their current BM. Locating their BM within the taxonomy indicates which dimensions must be adapted to transform an I3.0 BM into an I4.0 BM. The characteristics of the taxonomy and the case examples may inspire practitioners about how to innovate their BM, and allow managers to discover BMI opportunities. The 13 archetypes provide guidance for the transformation process by specifying the relevant meta-dimensions that the BMI affects. Firms can use archetypes and related cases in an ideation phase to identify options for BMI and assess their implementation in the firm’s context.

The main limitation of our work is the lack of available case studies. We could only find 15 case studies about I4.0 BM innovators with sufficient information for further analysis. Additionally, we do not have access to quantitative data showing how successful the analyzed cases are.

Future research can build on the taxonomy and archetypes. The taxonomy structures characteristics of I4.0 BMs and the archetypes show general, distinct types of I4.0 BMs. This helps future research to explain and analyze I4.0 BMs and BMIs more precisely. Additional case studies can further investigate the use of specific digital manufacturing and integration techniques, products and services and their influence on competitive advantage. Future studies can use the taxonomy and the 13 archetypes to analyze the co-occurrence of archetypes and dominant, digital transition paths from I3.0 to I4.0 BMs.

Acknowledgement

This research is funded by the German Research Foundation (Deutsche Forschungsgemeinschaft – DFG) as part of the ‘Collaborative Research Center 768: Managing cycles in innovation processes – Integrated development of product service systems based on technical products’ (TP C1), and the Center for Very Large Business Applications (CVLBA)@TUM.

REFERENCES


Archetypes for Industry 4.0 Business Model Innovations


