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Potentials for AI-Based Data-Driven Business Models in Industry 4.0

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Short Paper

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Abstract

Whereas the topics of artificial intelligence (AI) and business model innovation have attracted significant attention in academic research, publications at the intersection of both topics are rather sparse. In response, this paper attempts to interconnect the topics conceptually. In particular, it focuses on AI-driven business models in the context of Industry 4.0, highlighting examples and applications in the industrial context. In industry, first applications of AI applications have been known since several decades, such as in pattern recognition by cameras for failure detection. While applications in process or quality optimization have been improved since then, the clear connection to business models is not always clear. Therefore, this paper attempts to differentiate between examples of AI-driven business models that monetize, e.g., process optimization, or data-driven approaches of entire industrial platforms. In doing so, the present paper presents an overview of categories for AI-driven business model innovation across several industrial examples. As a result, future research can adopt and advance this overview to categorize research at the intersection of AI, business model innovation, and Industry 4.0.

Keywords: Industry 4.0, Industrial Internet of Things, Digital Transformation, Business model innovation, Artificial Intelligence, AI

Introduction

In extant literature, the topics of artificial intelligence (AI) and business model innovation have attracted significant attention. Nevertheless, publications at the intersection of both topics, AI and business model innovation are rather sparse (e.g., Anton et al., 2021; Garbuio and Lin, 2019). For instance, a Scopus search with a search string connecting the three topics reveals that only a few conference proceedings and journal articles appear, while mostly focusing on other main contents. Since research at the interconnection of Artificial Intelligence, business models, and Industry 4.0 remains less described in extant literature in comparison to a large number of publications in the respective topics in isolation, this paper addresses this research gap in the following.

In response, this paper attempts to conceptualize the topic in the context of digital transformation of Industry, most commonly known as Industry 4.0 (Kagermann et al., 2013; Lasi et al., 2014). Since Industry 4.0 enables several novel data-driven business models based on data analytics and AI (Frank et al., 2019; Müller, Buliga and Voigt, 2018), this research setting promises several insights and was therefore chosen for this paper.

Background

Industry 4.0

The concept of Industry 4.0 was introduced as "Industrie 4.0" in 2011 by the German government. The term Industry 4.0 refers to a fourth industrial revolution, following the three previous industrial revolutions, the first industrial revolution based on steam power, the second based on electrification and mass production, and the third based on automation (Kagermann et al., 2013; Lasi et al., 2014).

The concept of Industry 4.0 houses a multitude of technologies but can be converged towards two base technologies that enable most of the potentials (Kagermann et al., 2013; Lasi et al., 2014): Cyber-Physical Systems and the Internet of Things. Due to the latter technology, Industry 4.0 is sometimes also referred to as the Industrial Internet of Things (IIoT). Based on the data generation, data collection and transmission, and data analytics, technologies like Artificial Intelligence (AI) augment the potentials of data-driven optimization and business models (Frank et al., 2019; Müller, Buliga and Voigt, 2018), as described in the next section.

Industry 4.0 is based on three central characteristics that are enabled by the two base technologies above, among further: Horizontal integration, i.e., digitally enabled interconnection across the supply chain, vertical interconnection, i.e., digitally-enabled interconnection across company functions, and end-to-end engineering, i.e., across the entire product lifecycle, from production and product usage to recycling (Kagermann et al., 2013; Lasi et al., 2014).

Business Models in the context of Industry 4.0

The above-named three central characteristics of Industry 4.0 enable several potentials on an operational level. Further, novel data-driven business models, based on data collection, transmission, and analytics are enabled (Frank et al., 2019; Ibarra, Ganzarain, and Igartua, 2018; Müller, Buliga and Voigt, 2018; Weking et al., 2018). Through the interconnection of entire supply chains, industrial ecosystems are expected to emerge, which are based on platform-based business models that enable mutual sharing, analysis, and learning from data generated (Schmidt et al., 2022).

Business models have been described in several classifications or conceptualizations, such as the Business Model Canvas by Osterwalder and Pigneur or others. Most of these classifications refer to three central elements: value offer, value creation, and value capture (Chesbrough, 2010; Foss and Saebi, 2017): Value Offer refers to the products and services offered to the customer, value creation how those products and services are realized, also including suppliers and partners, and value capture how the value offer is monetized, i.e., how money is generated based on the products and services offered. The technological enablers within Industry 4.0, most notably Cyber-Physical Systems and the Internet of Things, require

business models to be adapted accordingly in order to unlock the potentials (Baden-Fuller and Haefliger, 2013; Chesbrough, 2010; Foss and Saebi, 2017; Rachinger et al., 2019).

Artificial Intelligence in Industrial Application

Artificial Intelligence (AI) applications can be observed in a multitude of industrial applications. For instance, camera systems for quality control of parts based on machine learning is a well-known application that is well-known since several decades (Demlehner et al., 2021). In this context, it is worth noting that AI receives a certain level of unclear definition, rather overusing the term for algorithms than "real" AI and overestimating the newness of a technology that is in usage since decades. Still, since the technology has evolved significantly over the last decades, applications for AI-driven process optimization have been published increasingly in extant literature. In particular, the potentials of combining AI and business model innovation have been described in extant literature, but remaining sparse in extant publications (e.g., Anton et al., 2021; Garbuio and Lin, 2019). However, industrial applications of data-driven business models based on AI remain less described than in business-to-consumer (B2C) contexts with significantly more publications.

Requirements for AI-based business models in the context of Industry 4.0

Overview of Digital Business Models in Industry 4.0

Figure 1 below presents three forms of Value Capture Mechanisms for Digital Business Models in Industry 4.0 based on Müller and Buliga (2019).

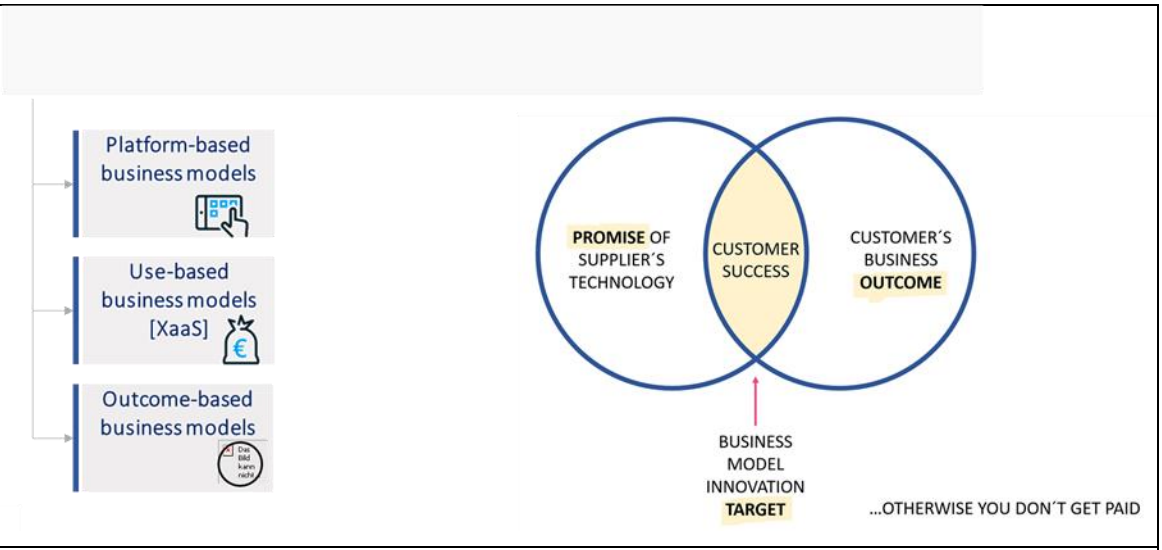

Figure 1. Three archetypes of Value Capture mechanisms for Digital Business Models in Industry 4.0

Specific characteristics of AI-based business models

Table 1 below extends figures 1 and 2 regarding specific applications of AI applications in Value Creation, Value Offer and Value Capture.

Table 1. Categories of AI-driven Business Models in Industry 4.0 and specific characteristics of Value Creation, Value Offer and Value Capture

Category	Value Creation	Value Offer	Value Capture
Platform-based business models	Data collection and analysis across entire value chains or ecosystems enabled by AI, serving multiple customers. Example: • Automation of human-based processes and anonymous integration of (confidential) data by several parties	Sharing data allows multiple stakeholders to optimize existing or uncover unknown potentials. Example: • Automated price negotiations on supply and purchasing platforms	Subscription model for Usage, Pay-per-use, Pay-per-optimization Example: • Payment per optimized negotiation for both parties
Use-based business models	Data collection and analysis by AI is conducted constantly, but presentation and evaluation are specific. Example: • Data analysis for production and logistics layout planning	Optimization and insights regarding existing processes, but only when needed for customers. Example: • Layout optimization for production plants or supply chain design	Pay-per-use, Pay-per-feature Example: • Payment per reduced planning time for layout planning
Outcome-based business models	Data collection and analysis based on AI that is combined with specific, individual services and knowledge. Example: • Process optimization or predictive capabilities based on existing data	Services targeted for specific purposes, such as reducing downtime or improving quality, combined with services. Examples: • Predictive maintenance • Visual quality control and object tracking	Pay-per-output, Pay for guaranteed results Example: • Payment per reduced downtime or energy consumption

As illustrated in Table 1, different domains of AI have specific impacts on value creation, value offer and value capture mechanisms within business models. Thereupon, the following section develops several research gaps for AI-driven business models in Industry 4.0.

Research gaps for AI-driven business models in Industry 4.0

Based on several examples of AI-driven business model innovation presented in the previous section, several opportunities for future research are described:

- **Understanding the role of AI in Value Creation, Value Offer and Value Capture:** Since AI is one of the few technologies that can be integrated into all elements of the business models, this interrelation between, e.g., process optimization and price negotiations in purchasing must be understood better.
- **Integration of Small and Medium-Sized Enterprises (SMEs):** Since many SMEs do not have the benefits for AI-usage for themselves but are subject to or shall provide data to AI-based analyses, those must be integrated better. One example includes neutral platforms for data analysis such as Gaia-X, that SME (Estensoro et al., 2021; Horváth and Szabó, 2019). Likewise, start-ups can play a vital role in developing niche-specific AI solutions as well as implementation (Cesinger, Vallaster and Müller, 2021).
- **Supply chain or platform-spanning solutions of AI applications:** As several authors emphasize, only supply-chain spanning solutions that integrate production and logistics processes of individual enterprises can unlock the full potentials of Industry 4.0 (Lassnig et al., 2022; Lerman et al., 2022).
- **Understanding the challenges of AI for humans and organizations:** In order to implement AI-based business models successfully, the fears and doubts of employees must be understood better (Demlehner et al., 2021)

Conclusion

This paper extends the view on Digital Business Models regarding the aspects of AI-driven business model innovation, relating to Value Creation, Value Offer, and Value Capture mechanisms. Thereupon, the paper develops a several research gaps to foster future research in this area.

Regarding its limitations, the paper is not based on empirical data and can thus only present a conceptual overview on the topic. Hence, empirical research at the intersection of business model innovation, Industry 4.0, and AI-enabled Value Creation, Value Offer and Value Capture mechanisms. Further, it is possible that several publications include AI-based business model innovation, but do not state the technological foundations explicitly. Hence, a more fine-grained literature overview could present additional insights in addition to the research gaps presented.

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