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From a theory of production to data-based business models

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Abstract. Producing companies are challenged by competition in global markets, in which customers have in general a strong negotiation position. In order to improve their competitive situation, companies constantly attempt to decrease production costs. However on the one hand, it can be observed that companies often do not only have an issue in decreasing their production costs but also in the determination of current production costs as basis for improvements. On the other hand, producing companies face an increasing volume of production data in the course of Industrie 4.0. This data is expected to be potentially usable as additional sales asset. Yet, especially traditional companies do not know how to translate generated production data into incoming cash flows. In order to tackle both named issues, this paper presents both an overview of data-based business models for producing companies and a tool for increasing transparency of production costs in global production networks.

Keywords: Theory of production, business model, global production network.

1 Introduction

In recent years, customers of producing companies demand increasingly individualized products at similar or even lower costs. In competitive markets companies have responded to this trend by increasing their product variants. Formerly cost-efficient oriented production configurations have at least partially been transformed into flexible job shop structures. [1] While decreasing the transparency of cost allocation to jobs and machines, the challenge of high quality but efficient cost calculations for new orders has increased. This challenge does not only affect local production sites but even more complete global production networks. [2] However, due to global markets, that have developed from supplier to customer ones, cost pressure is another important influencing factor for producing companies. Thus, for decreasing costs an important first step is creating transparency of production costs in the production network.

In the last decade, the use of new production technologies, e.g. 3D printing, could widely be observed. [3] In parallel, newly designed machines were equipped with numerous sensors, too. Not only digitization but also the connection of machines is a major trend that is commonly known as Industrie 4.0. [4] As a result, companies face a significant increase of production data in growing granularity, that have the potential not only to be used for increasing transparency but also to be sold as a good itself.

This paper aims to give guidance for producing companies in the identification of the right data-based business model for their need and to increase transparency of global production network costs as particular example of a data-based business model. The remainder of the paper is structured as follows. In section 2 a brief introduction to the research background of data-based business models is given. In section 3 different data-based business models are presented that have been researched in the past. As a particular example of one of the derived business models, the concept and implementation of a tool for increasing transparency of production costs in global production networks is presented in section 4. In section 5 the main findings are summarized.

2 Towards a theory of production

In the cluster of excellence "Integrative Production Technology for high-wage Countries" at RWTH Aachen University, research was conducted on developing a generic theory of production. This theory aimed to increase the assessability of individual, technological and managerial advances with respect to a company's profitability. The developed theory of production relies on a number of both cost and profit drivers.
Quantifying relevant parameters of those cost drivers supports the determination of different costs for newly designed products that can potentially be produced with different technologies. Comparing the advantageousness of the considered technologies, a profound and objective decision on the best alternative can be made. By doing so, the trade-off between efficiency and flexibility is objectified. [3]

Production research often focuses on quantifying cost drivers. Yet, researching profitability drivers of companies is an important objective, too. Therefore, an investigation of data-based business models that are built on or are supported by Industrie 4.0 has been conducted in the transition phase from the above mentioned cluster of excellence to the new cluster of excellence of RWTH Aachen University called "Internet of Production". Against this backdrop, the intention of this paper's underlying research is to provide answers to the question, on how digitized manufacturing firms can use production data to increase profits through business model innovation.

The results of this research are presented and validated in the following sections.

3 Data-based business models

3.1 Foundations of business models

Digitization revolutionizes the production industry with respect to new possibilities of collaboration among individuals, machines, and firms. In order to leverage these opportunities, the German federal government has adopted Industrie 4.0 as a key pillar of its Hightech Strategy 2020. [5] In this context, Industrie 4.0 involves ICT-caused radical technological and organizational changes within the production industry. [6] A central element of Industrie 4.0 is the so-called "smart factory", which enables ICT-based, flexible, autonomous and self-optimizing production systems and networks. [7] Within smart factories processes, machines, products, and resources are represented via cyber-physical systems (CPS) and Industrial Internet of Things (IIoT) as a "digital twin". [8,9] Besides the advantages of smart factories (e.g. improved flexibility, productivity, and transparency), it also offers new opportunities with respect to data availability and use in in new business models. [10]

Based on the value chain concept by Porter, the data value chain serves as a base for exploring monetization opportunities of production data. [11] Referring to the information systems-based conceptualization that includes a hierarchical link of data, information, knowledge, and wisdom (DIKW), corresponding management activities for the four phases, and analytical methods that enable the transition between the phases, it is proposed that firms can directly generate value from production data in all four phases (**Fig. 1**). [12–14] Actual monetization of production data can be achieved through (innovation of) data-based business models.

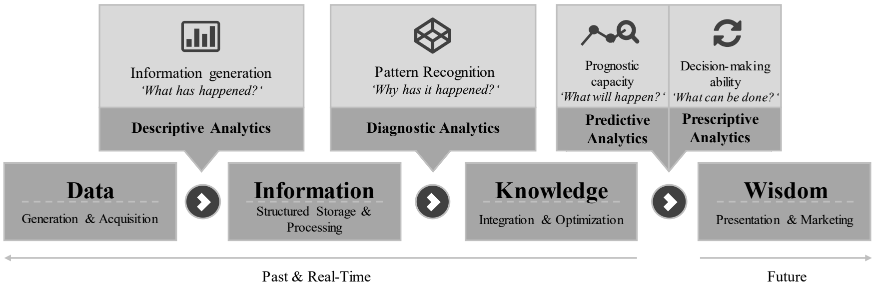

Fig. 1. Data value chain [12–14]

As shown in **Table 1**, Osterwalder & Pigneur [15] and Holm et al. [16] conceptualize business models via four dimensions, i.e. value proposition, value delivery, value creation, value capture. These, in turn, involve nine components, i.e. value proposition, customer segments, channels, customer relationships, key resources, key activities, key partnerships, revenue streams, and cost structure.

Casadesus-Masanell & Zhu [17] describe business model innovation (BMI) as a change of key elements of organizations and their business logic to generate additional value for stakeholders. As for production data, existing or new data can be used to generate new business models or improve existing ones to make them fully data-based.

[18] Data-based business models can be categorized according to the use of data, i.e. solely firm-internal use of data, sharing data with partners, trading data as a product, or making data available for free. [19] Against this backdrop, a holistic and practice-oriented framework was developed that involves production data-based, innovative business models for the production industry in high-wage countries.

Table 1. Business model components

Meta-components	Components	Description
Value proposition	Value proposition	Gives an overall view of a company's bundle of products and services.
Value delivery	Customer segments	An organization serves one or several customer segments.
	Channels	Value propositions are delivered to customers through communication, distribution, and sales channels.
	Customer relationships	Customer relationships are established and maintained with each customer segment.
Value creation	Key resources	Key resources are the assets required to offer and deliver previously described elements.
	Key activities	Number of key activities performed by key resources.
	Key partnerships	Some activities are outsourced and some resources are acquired outside the enterprise.
Value capture	Revenue streams	Revenue streams result from value propositions successfully offered to customers.
	Cost structure	The BM elements result in the cost structure.

3.2 Framework for production data-based business models and innovations

As starting point for the development of a framework for production data-based business model types and innovation, a systematic literature analysis on keywords, such as "data-based business models", "data monetization" and "data strategy" has been conducted. Referring to Nickerson et al. the business model categories that evolved from the literature review have been structured and selected so that the remaining business model categories form a mutually exclusive and collectively exhaustive framework. [20] Business models that are not applicable to production firms have been excluded. Besides, business models that are not based on proprietary data, but only use external data, have been excluded, too.

The remaining business model types have been categorized by the authors across the data value chain in three core categories, i.e. “measure”, “infuse”, “apply” (first level in **Fig. 2**) and visualized in a framework that is presented in **Fig. 2**.

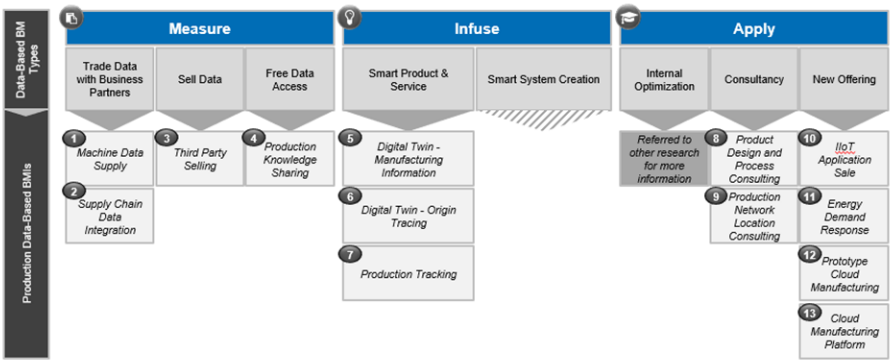

Fig. 2. Derived framework for data-based business models

Infuse entails data-based business model types that include DIKW in specific products, services or networks of products and services. By making products and services more engaging for customers, these business models enable firms to expand their revenue streams. [14]

Apply involves those business model types that apply knowledge and wisdom without combining it with existing products and services. Predictive and prescriptive data analytics enable firms to identify patterns, relations, and future outcomes. [21,22]

Fig. 2 depicts the corresponding eight innovation paths (second level in **Fig. 2**) for digitized production firms that, in turn, are distributed in thirteen production data-based BMIs (third level in **Fig. 2**).

4 Validation

The business models have been evaluated using different criteria, i.e. implementation complexity, upside potential and downside risks. Within the proposed framework of data-based business models in section 3, the business model production network location consulting, as example of the innovation path "Consultancy" (business model type "apply" in **Fig. 2**), has been validated by developing and implementing a data-based online tool for designing production networks. Production network location consulting derives its competitive advantage over other consultancies by leveraging actual production data from smart factories. For this reason, the software demonstrator OptiWo has been developed at the Laboratory for Machine Tools and Production Engineering (WZL) at RWTH Aachen University with the goal of supporting product allocations and distributing value added in global networks. Nowadays, production network designers face the challenge of a globalized world with linked markets, calling for shorter planning cycles and with production networks demanding to be adapted more rapidly. Therefore, all production network decisions need to be based on viable data at a comprehensive level of aggregation in order to make faster as well as more profound decisions in uncertain business environments. [8] Relevant data is spread over different IT systems, such as ERP, MES or PDM systems.

The OptiWo tool creates value for the end user by streamlining planning and decision-making processes through focused visualization and precis and transparent dissection of production network interdependencies. Considering that designing production networks involves many uncertain influencing factors, the assessment of dependencies is crucial. Therefore, OptiWo takes into account different target values such as visualizing costs, delivery times and network risks to allow a profound network analysis.

The necessary prerequisite for using the tool is the availability of data on production sites, sales regions, demand quantities, production resources, processes and transport routes. The data can be entered directly in the tool at a freely selectable aggregation level. Therefore, the user can decide for each project which products, processes and cost types should be considered for network analysis. The OptiWo tool works based on a total landed costs approach, where all production costs of a product, including all transport costs and customs duties, are included. [23] Hence, fixed costs such as basis costs for production sites and depreciation costs as well as variable costs such as direct and indirect personnel, variable machining costs and purchases parts are taken into account. A major advantage of the tool is the freely selectable level of detail of the data acquisition and following the level of detail for network visualizations. At the same time, the tool supports the user through the process of data acquisition and displays the data requirements of the relevant areas in successive menu tabs.

After data collection, the tool summarizes the results of the network analyses in a “viewer” as shown in **Fig. 3**. The viewer offers several interactive visualizations where the user gets an overview of the existing production network as well as a deeper insight, if desired by several mouse over effects and access to additional information. In detail the named network target values costs, delivery times and network risks are visualized for each production site. Thus, the connection between these target values is visualized in a user-friendly way, which supports the user in understanding the impact of his decisions about product allocations and value added distribution.

Fig. 3. Visualization of transport relations, delivery times and costs in a production network

As a result, the user gets a holistic transparency about the performance of the production network and can derive specific needs for action to improve the network such as distributing value added or decreasing transport efforts.

5 Summary and outlook

The approach presented in this article has been developed to illustrate the potential of data-based business models in the field production management. In particular, the developed framework includes three core categories of business model types with eight corresponding innovation paths and thirteen specific production data-based BMIs. Thereby, the framework depicts the spectrum of strategic opportunities that producing firms can leverage to generate value by using proprietary production data. While the presented demonstrator tool OptiWo mainly focuses on increasing transparency over the existing distribution of value added in production networks, the next step will be to support the decision maker in proactive designing the production network by illustrating different network scenarios and the assessment of their impact on strategic targets. By supporting the network designer in creating different network scenarios, sensitivity analyses can be performed which is becoming increasingly important in uncertain business environments. Furthermore, the tool-based decision support should be developed further with regards of identifying an optimal interaction of data-based decision preparation and integrated expert knowledge. Therefore, different user groups should be surveyed to analyze the interaction with the tool and to evaluate the different tool features. Thus, a new way of strategic decision-making can be developed by autonomous decision preparation for enabling decision makers to focus on the value-adding part of decisions in designing future production structures.

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