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Monozukuri capability and dynamic product variety: An analysis of the design-manufacturing interface at Japanese and German automakers

Katsuki Aoki[a,*], Thomas Staeblein[b]

[a] School of Business, Meiji University, 1-1 Kanda-Surugadai, Chiyoda-ku, Tokyo 101-8301, Japan
[b] School of Management, Technische Universität München, Arcisstr. 21, 80333 München, Germany

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ABSTRACT

The importance of the design-manufacturing interface has increased in the age of the globalization of the automotive industry in which automakers need to meet a wide variety of customer demands globally. However, studies on the automotive industry have not yet fully developed a theoretical insight into the design-manufacturing interface in connection with product variety. This paper aims to provide insights into *monozukuri* ("manufacturing" in a broad sense, including production, product development, and supply chain management) capability for managing dynamic product variety by comparing industrial practices between Japanese and German automakers. We analyze dynamic variety and monozukuri capability based on the framework that connects Fujimoto's concept of monozukuri capability to Galbraith's information processing model. By doing so, we aim to highlight the effectiveness and limitations of the Japanese automotive industry in the age of the globalization of the automotive industry.

1. Introduction

Since the early 1980s, Japanese management practices have provided many valuable insights into the studies of operations management including product development (PD) and innovation (Schonberger, 2007). The rationales and practices of Japanese firms related to innovation have been reported in mainly three different fields: Kaizen or process innovation (Adler et al., 2009; Aoki, 2008), case-based reports of innovative Japanese firms (Clark and Fujimoto, 1991; Morgan and Liker, 2006) and comparisons between Western and Japanese PD practices (Edgett et al., 1992; Verworn et al., 2008).

The concept of "*monozukuri capability*" is sometimes used for discussing the uniqueness of Japanese management practices in manufacturing industries compared to Western ones. The Japanese word "*monozukuri*" can be translated into "manufacturing" in English. However, monozukuri goes beyond a narrow understanding where "manufacturing" simply refers to production but actually includes all related activities such as product development, process control, and supply chain management. Different from Western management methods where there is a clear boundary between these different activities, in the concept of monozukuri these activities are integral and organically linked. This is related to the Japanese way of thinking that makes no clear distinction between the parts and the whole (Nonaka and Takeuchi, 1995). Monozukuri capability thus includes management capability to engage in manufacturing activities from such a broad, organic perspective.

Past studies on monozukuri capability have mainly focused on cases in the automotive industry. The automotive cases in the 1990s highlighted the effectiveness of Japanese makers' monozukuri capabilities based on the international comparison of operational excellence in areas such as production (Womack et al., 1990) and PD (Clark and Fujimoto, 1991). The 2000s saw a development in the kinds of studies being carried out to include attempts to understand a monozukuri capability that integrates different functional areas, such as procurement, production and sales (Aoki et al., 2014; Holweg and Pil, 2004). These studies argue that the effectiveness of monozukuri capabilities needs to be further studied, taking into account the level of product variety offered to customers (external variety).

While many of these automotive studies have centered on product variety in a static dimension (e.g. Aoki et al., 2014; Staeblein et al., 2011), far less attention has been paid to product variety in a dynamic dimension, or dynamic variety. In the automotive industry dynamic variety is created through the introduction of new models (Holweg and Pil, 2004), and therefore closely linked to the area of PD, or product innovation. However, the increase of dynamic variety also has an influence on the area of mass-production and process innovation. An increase in the number of vehicles being produced in a manufacturing plant over a period of time requires more efficient transfer processes

* Corresponding author.
E-mail addresses: kaoki@meiji.ac.jp (K. Aoki), thomas.staeblein@tum.de (T. Staeblein).

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between design, development, planning and operation. The longer the plant spends for the transfer processes, the lower the operation rate of that plant becomes. Therefore, monozukuri capability for managing dynamic variety straddles the areas of both product innovation and process innovation, and is closely connected to the concept of design-manufacturing interface.

Considering the recent progress of globalization in the auto industry, such a capability should be highly valued. In order to compete in the global market, automakers need to meet a variety of global customer demands by producing a range of models for certain price categories, such as luxury and economy, and for different purposes, such as sedan, sports, and SUV. Furthermore, the advancement of technology related to automobiles, such as green, safety and information technologies, increases the need for automakers to offer cars that include various technologies, such as electric, hybrid, and fuel-cell vehicles (Pinkse et al., 2014), to customers at various prices. These makers also need to meet requirements from governmental regulations, such as the reduction of carbon dioxide (CO2) emissions (Holweg, 2014). At the same time, it is crucial for automakers to achieve a cost advantage over competitors in order to survive the globally intensified competition. Although the design-manufacturing interface plays a key role for automakers in meeting the high requirements for dynamic variety and cost efficiency simultaneously, this research field remains relatively undeveloped.

Automakers' strategies and capabilities to meet globally diversified customer needs are also relevant to discussions in the field of innovation studies. Abernathy and Utterback's (1978) life cycle model explains how product innovation will be replaced by process innovation over time. Innovation researchers have extended or challenged this basic model and illustrated a variety of relationships between product and process innovations (e.g. Brem et al., 2016; Lim et al., 2006). Some researchers show that product innovation follows process innovation (e.g. Barras, 1986; Linton and Walsh, 2008); others highlight interdependent relationships between the two (Ballot et al., 2015; Hullova et al., 2016; Kurkkio et al., 2011). Fujimoto (2014) states that Abernathy and Utterback's model can explain only the early phase of the automotive industry till the 1960s, and that both product and process innovations increased again afterwards. Our paper shows a novel implication that has been witnessed recently (2000–2013) for innovation studies by analyzing the role of monozukuri capability that allows manufacturers to actively pursue product and process innovations simultaneously. Particularly we provide an explanation of relationships between product and process innovations in the phase where makers need to meet a globally diversified customer demand.

To summarize, our paper aims to explore the study of "monozukuri capability for managing dynamic variety" and provide insights into the theme of this special issue, "Innovation in the East-Asian Automotive Industry", by tackling the following research questions:

1. What role does monozukuri capability play in managing dynamic variety in the age of globalization of the automotive industry?
2. What aspects of monozukuri capability for managing dynamic variety are unique to Japanese automakers as an example of the East-Asian automotive industry?

In order to address these research questions, we conducted case studies of the industrial practice at Japanese and German automakers. The remainder of the paper is structured as follows: The next section provides the theoretical background on monozukuri capability and product variety, which is followed by an explanation of our research framework and research methods. Then, key findings on Japanese automakers' monozukuri capability are presented, and these are compared with that of German makers. Here, we conduct a quantitative analysis of industrial data to present factual evidence on the comparison of monozukuri capabilities between Japanese and German automakers. This is complemented by a qualitative analysis on individual automakers' behavior and strategy to provide a better understanding of the practical aspects of the monozukuri capabilities of these makers. Finally, the insights of this paper as well as future challenges are considered in the sections of discussion and conclusions.

Functional capability	1) Operational management	3) Product development
Integrative capability	2) Order-to-delivery process	4) Design-manufacturing interface
	Static variety	Dynamic variety

Fig. 1. Classification of studies on monozukuri capability and product variety.

2. Monozukuri capability and product variety

"Monozukuri capability" denotes an organizational capability for achieving excellent performance related to manufacturing in a broad sense, including production, PD, and supply chain management (Aoki et al., 2014; Clark and Fujimoto, 1991; Fujimoto, 1999). In order to better fit the purpose of this special issue, this section mainly focuses on the studies of such a capability that highlight characteristics unique to the Japanese automotive industry compared to Western ones. Past studies on monozukuri capability can be classified in connection with product variety using the 2-by-2 matrix shown in Fig. 1.

The horizontal axis in Fig. 1 indicates the dimension of product variety; whether researchers discuss monozukuri capability for managing static variety or dynamic variety. Static variety refers to product variety that is offered to end-customers at a certain point in time (i.e. external variety, Staeblein et al., 2011), an example of which is that Volkswagen Golf offered customers three different body-types, 16 power trains, 221 paint-and-trim combinations, and 26 factory-fitted options in Europe in 2002 (Pil and Holweg, 2004). Dynamic variety, on the other hand, "refers to the choice that is offered over time, resulting from changing time periods between introductions of novel or modified products" (Scavarda et al., 2010: 207). The vertical axis indicates the nature of monozukuri capability related to the scope of functional areas; whether researchers discuss monozukuri capability for managing an individual function, such as production, quality, or PD, or for integrating different functional areas in a supply chain.

The first quadrant includes studies on operational management for a specific function. A huge number of studies related to Japanese management practices, such as quality management (Linderman et al., 2004; Schonberger, 2007), and kaizen/shopfloor management (Adler et al., 1999; Aoki, 2008), are classified in this quadrant. Although these studies do not always refer directly to product variety, most of the studies presuppose that Japanese management practices effectively manage the cost-variety tradeoff. These studies tend to explain the effectiveness of Japanese makers' monozukuri capabilities by highlighting the flexibility of shopfloor workers who can achieve high efficiency in their routinized activities as well as continuously improve these activities by exploring new ideas (Adler et al., 2009; Brunner et al., 2010). This aspect of monozukuri capabilities is closely connected to studies on organizational ambidexterity (Benner and Tushman, 2003, 2015), which enables organizations to successfully deal with productivity dilemma (the pursuit of efficiency decreases flexibility, Abernathy, 1978).

Studies classified in the second quadrant highlight monozukuri capabilities for integrating different functional areas in the automotive supply chain. Holweg and Pil (2004), drawing on MacDuffie et al. (1996), provide a framework to study the impact of product variety on the automotive supply chain, and discuss the overall structure of an order-to-delivery process for addressing external variety. Tomino et al., (2009, 2011), based on Japanese cases, further discuss the role of an integrative monozukuri capability for managing the order-to-delivery process in effectively promoting mass-customization strategies. Finally,