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The unique and complementary effects of manufacturing technologies and lean practices on manufacturing operational performance

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ABSTRACT

This study investigates the unique and complementary effects of manufacturing technologies and lean practices on operational performance of manufacturing firms. Despite the importance of understanding how various resources are interrelated within firms, there have been few studies focusing on this area. Using data collected from 186 manufacturing plants in Thailand, we found that both manufacturing technologies and lean practices have unique effects on a range of operational performance dimensions, including quality, lead-time, flexibility, and cost. More importantly, however, we also found that both organizational resources have complementary (or synergistic) effects on those operational performance dimensions. Based on the research findings, we offer theoretical and practical insights which support the importance of building strong manufacturing technologies and lean practices that maximize operational performance.

1. Introduction

Global competition has intensified pressure on manufacturing plants to improve along multiple dimensions of operational performance. These operational performance dimensions include product quality, lead-time, flexibility, and cost (Boyer and Lewis, 2002; Hayes and Wheelwright, 1984; Tan et al., 2004). Consequently, numerous studies have attempted to identify the various resources that can be utilized to help firms to excel on these multiple operational dimensions. Based on the past research on this topic (Das, 2001; Swamidass, 2003; Zahra and Das, 1993), manufacturing resources can be grouped into two major categories, namely manufacturing technologies and lean practices. Manufacturing technologies refer to certain types of technologies such as hardware and computer programs, including computer-aided design (CAD), computer-aided engineering (CAE), computer-aided manufacturing (CAM), computer numerical control (CNC) machines, robots, and enterprise resource planning (ERP) systems, whilst lean practices are concerned with manufacturing techniques and know-how such as total quality management (TQM) and just-in-time (JIT) manufacturing.

A number of empirical studies have investigated the effect of manufacturing technologies and lean practices on different measures of operations performance (Swamidass, 2003; Zahra and Das, 1993). However, most of these studies focus on either manufacturing technologies (Beaumont et al., 2002; Kotha and Swamidass, 2000) or lean practices (Cua et al., 2001; Flynn et al., 1995). It is now common for manufacturing firms to adopt both manufacturing technologies and lean practices and therefore, it is important to understand the synergistic effects of manufacturing technologies and lean practices on improving operational performance. However, only few studies (Challis et al., 2002) have brought together the aspects of manufacturing technologies and lean practices into a single study and tested their unique and synergistic effects.

Drawing on the resource-based view of the firm (RBV) theory and complementarity theory, we argue that combining different resource bundles may result in synergistic effects on operational performance (Jeffers et al., 2008). However, to date, only a few empirical studies have examined the interactive effects of manufacturing technologies and lean practices on multiple dimensions of operational performance. For example, Boyer et al. (1997) examined the interaction between different advanced manufacturing technologies (AMTs), which are similar to the manufacturing technologies in this study, and infrastructure on three performance measures,

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namely growth, profitability, and flexibility. They argued that investments in AMTs are more likely to lead to improved performance, if these are supported by improvements in the manufacturing infrastructure of the company. Boyer et al. (1997) and Zhou et al. (2009) showed the interaction effects of the adoption of AMTs and investments in infrastructure on performance. Swink and Nair (2007) tested the interaction between the usage of AMTs and design-manufacturing integration (DMI) on five dimensions of operational performance. Their findings showed that the interaction effects were positive on quality, delivery, and process flexibility, but not on cost efficiency and new product flexibility. Our study builds on these two studies by testing the interactive effects of manufacturing technologies and lean practices on four major dimensions of operational performance, namely product quality, lead-time, flexibility, and cost. Specifically, we extend the works of Boyer et al. (1997) and Swink and Nair (2007) by expanding the scope of both lean practices and manufacturing operational dimensions.

The rest of the paper is organized as follows: first, we develop a set of hypotheses concerning the relationships between manufacturing technologies and lean practices, and their effects on four major operational dimensions of manufacturing performance, namely cost, product quality, lead-time, and flexibility. Then, we present the research methodology and the results of our analysis. Finally, we discuss the theoretical and practical implications of the findings.

2. Literature review and hypothesis development

In this study, the resource-based view (RBV) is used as a theoretical lens to examine the relationship between resources (e.g., manufacturing technologies and lean practices) and operational performance. RBV argues that business organizations, even within the same industry and the same operational environment, are heterogeneous in their resources and this heterogeneity can explain competitive, even sustainable, and performance differentials (Hackman and Wageman, 1995; Ketokivi and Schroeder, 2004). Resources are defined as all assets, organizational processes, firm attributes, information, knowledge, technologies etc. controlled by a firm that enables it to conceive of and implement strategies that improve its efficiency and effectiveness (Barney, 1991). Firm resources are the firm's strengths. Resources are thus defined by virtue of their relationship to performance, and the relationship between resources and performance is the key outcome of interest (Amundson, 1998).

RBV theory has been applied in a number of studies in the manufacturing context. By applying the RBV, Zahra and Das (1993) propose a framework that examines how manufacturing technologies and lean practices deployed as organizational resources are reflected in competitive performance. In the context of our study, RBV provides a theoretical lens for examining three issues. First, we draw from RBV to examine the effectiveness of both manufacturing technologies and lean practices as firms' resources which are valuable and non-imitable as reflected in the firms' performance. Second, RBV guides us to examine the unique effect of both manufacturing technologies and lean practices in predicting different types of performance. In their study, Ketokivi and Schroeder (2004) propose that, based on the premise that each practice–performance relationship might be unique, the organizational determinants of high conformance quality may be different from those of flexibility. Similarly, Cua et al. (2001) also argue that different configurations of basic techniques and common practices affect specific aspects of capabilities. Third, in the light of RBV, we examine the synergistic effects between manufacturing technologies and lean practices in predicting different types of manufacturing performance. This is because a combination of different resources increases the complexity of resources which makes it more difficult to imitate by competitors; and, if the combined resources produce synergy, these would deliver higher performance than each of them could deliver by itself.

In the next two sections, the eight hypotheses examining the effects of manufacturing technologies and lean practices on the four dimensions of operational performance are developed and presented.

2.1. Relationship between manufacturing technologies and operational performance

Manufacturing technologies entails various technologies which are employed in different activities in manufacturing operations. Given a wide variety of technologies used, a number of authors (Adler, 1988; Cardoso et al., 2012; Kotha and Swamidass, 2000; Meredith, 1987; Rosenthal, 1984; Sohal et al., 2006) have considered manufacturing technologies as a multi-dimensional construct. In this study, Boyer et al.'s (1996) classification was adopted as a basis for identifying three groups (or components) of manufacturing technologies that are distinct but related to one another. The first component is design manufacturing technologies that comprise tools such as (CAD), (CAE), and computer-aided production planning (CAPP) that focus on product and process design issues. The second component is process manufacturing technologies, which enables efficient and flexible manufacturing processes and include technologies such as automated manufacturing (AM), real-time process control systems, CNC machines, and robots. The third group is administrative manufacturing technologies, which aid in internal and external communication, as well as planning of critical firm resources. These technologies consist of material requirements planning (MRP), manufacturing resources planning (MRPII), and enterprise resources planning (ERP) systems. Swink and Nair (2007) point to general agreement in the literature on this classification scheme which identifies these three aspects of manufacturing technologies.

As mentioned earlier, the effect of manufacturing technologies on various dimensions of operational performance has been recognized. Below, we elaborate on the arguments which lead to the hypotheses concerning the relationship between manufacturing technologies and each of the four performance measures (cost, quality, lead-time, and flexibility).

Low cost is often cited as the primary, realized manufacturing objective of manufacturing technology implementation (Adler, 1988; Esan et al., 2013). Ettlie (1988) found positive significant effects of AMT on cost reduction. AMT, specifically CIM technology, was linked to reductions in inventory levels and costs resulting from scrap and re-work (Ettlie, 1988; Heim and Peng, 2010). Similarly, Zairi (1993) reported that AMT is primarily adopted in response to changes in demand at economical costs and is introduced to combat costs and to enable users to compete as economically as possible. For example, the adoption of a CAD/CAM system allows the production system to release extra machine time; hence reducing costs and increasing productivity (Heim and Peng, 2010; Pagell and Krause, 1999; Patterson et al., 2004). Literature has also suggested the positive effect of administrative technologies on cost performance. MRPII, for example, offers information integration business processes linked to a central database that stores and delivers more accurate data and information compared to paper-based information and communication systems which potentially produce numerous errors (e.g., missing data, redundant data, and numerical errors), resulting from incorrect keying into the system, incorrect calculations based on numerical errors, and bad decisions based on incorrect or old data, (Ward and Zhou, 2006). MRPII also allows for the coordination of raw materials purchasing, facilitates the development of a detailed production schedule that accounts for machine