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Understanding the relationships of integration capabilities, ecological product design, and manufacturing performance

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ABSTRACT

Organizations increasingly adopt ecological product design techniques to lessen their harmful impacts on the natural environment. Theory about ecological product design remains in an early stage of development though. The present study focuses on organizational integration capabilities and their conceptual relation to ecological product design, such that they can be redeployed, expanded, and leveraged to affect manufacturing performance. Drawing on data collected from 769 Russian manufacturers and using structural equation modeling, this study shows that cross-functional integration and technological integration mediate the relationship between ecological product design and manufacturing performance. In this Russian context though, customer integration does not function as a mediator. These findings have implications for theory and practice related to both ecological product design and environmental operations.

1. Introduction

As global ecosystems continue to deteriorate, organizations face increasing pressure from various stakeholders to lessen the harmful impacts of their activities on the natural environment. In organizations' search for solutions to improve their environmental performance, their original focus was largely on reducing harmful emissions, effluents, and wastes due to manufacturing. More recently though, firms have adopted a more preventive approach and seek to minimize the environmental impact of their products by adopting eco-design principles (Hart, 1995). With an ecological product design (EPD) process, companies make products more sustainable throughout their lifecycle and attain a balance across environmental protection, economic prosperity, and social equity while also accounting for traditional product characteristics such as quality or cost (Gunasekaran and Spalanzani, 2012; Maxwell and van der Vorst, 2003).

In light of the increasing practical relevance of EPD, scholars also have started to investigate its antecedents (de Medeiros et al., 2014; Johansson, 2002; van Hemel and Cramer, 2002), related practices (de Pauw et al., 2014; Knight and Jenkins, 2009; Maxwell and van der Vorst, 2003), and outcomes (Plouffe et al., 2011; Pujari, 2006; Schrettle et al., 2014), typically by focusing on firm and project characteristics such as project leaders, top management commitment, or the work organization (Johansson, 2002). Yet this early-stage theorizing on EPD requires further development. Accordingly, we propose that certain organizational capabilities relate conceptually to EPD and thus can be redeployed, expanded, and leveraged to support EPD success. In traditional project management, cross-functional integration, customer integration, and technological integration are critical success factors for product development (Brown and Eisenhardt, 1995). We adopt this line of reasoning to propose that EPD implementation yields better results when a firm can draw on its integration capabilities.

In turn, this study makes several contributions to environmental operations literature. First, current research on EPD has sought mainly to identify more noticeable success factors, such as key organizational or project characteristics. We expand this view by also considering the underlying organizational routines and learning processes that affect the outcomes of EPD (de Medeiros et al., 2014). Second, we advance current theorizing on EPD that thus far has concentrated on its drivers and performance implications. We hypothesize that capabilities represent important mediating factors that affect the relationship between EPD and performance. In turn, we provide a more nuanced understanding of

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the mechanisms by which EPD affects performance (Mathieu et al., 2008; Rungtusanatham et al., 2014).

Third, we conduct this study in a novel and important national context, namely, the transitioning economy of Russia, which operated according to a planned system before 1990 but since then has gradually adopted a market system (Shinkle and Kriauciunas, 2010; Shinkle et al., 2013). The Russian business context thus is unique; whereas its overall foreign direct investment has increased in the past few decades, the share of Russian exports and imports as a percentage of gross domestic product has declined (Golikova et al., 2012). Compared with other former members of the Soviet Union, Russia lags on several development indicators, including the time required to start a business and the gross national income per capita (World Bank, 2014). Because most prior studies of environmental management in transitioning economies address Asia or South America, conducting this study in Russia provides a unique opportunity to explore whether Western theories about EPD, organizational capabilities, and performance hold in this distinct economic, political, and cultural context.

In Section 2, we review literature related to technological, internal, and external integration, as well as EPD and performance, to derive our theoretical background, research model, and hypotheses. We test the proposed model with structural equation modeling of data collected from 769 Russian manufacturers, to uncover the relationships among the model constructs. Finally, we discuss the results with a view toward their implications, as well as directions for further research.

2. Theory and hypotheses

2.1. Ecological product design

Ecological product design integrates environmental considerations in product design to decrease or even avoid negative environmental impacts upfront, rather than as an afterthought (Gunasekaran and Spalanzani, 2012). In this sense, EPD provides more advanced, proactive solutions to environmental problems and increases product value and utility. Between 30% and 80% of the environmental impact of a product can be determined at the design stage (Clark, 2007), which suggests interventions in these early stages may yield important environmental improvements.

We define EPD, also known as product stewardship (Hart, 1995) or design for the environment (Braungart et al., 2007), as a process of making products more sustainable throughout their lifecycle to attain balance among environmental protection, economic prosperity, and social equity, while also taking traditional product characteristics such as cost, quality, function, and technical issues into account (Chialin, 2001; Gunasekaran and Spalanzani, 2012; Maxwell and van der Vorst, 2003). In particular, EPD might include considerations to reduce resource requirements, replace hazardous or non-renewable materials, address health and safety issues in the manufacturing process, and facilitate reuse or recycling of components at the end of the product's lifecycle (Calcott and Walls, 2005; Fiksel, 1996; Snir, 2001; Wong et al., 2012). Existing frameworks help guide designs of more sustainable products by estimating and assessing their environmental impacts at their different life cycle stages (Kengpol and Boonkanit, 2011; Schrettle et al., 2014).

In considering the link between EPD and performance, most research focuses on their direct relationship; for example, Geyer et al. (2007) investigate products that have reached the end of their useful life and been subjected to remanufacturing (i.e., value recovery through the reuse of durable product components). They model methods to coordinate the production cost structure, collection rate, product life cycle, and component durability to maximize the production cost savings achieved from remanufacturing. Similarly, Pujari et al. (2003) document how EPD improves an organization's efficiency and effectiveness.

2.2. Dynamic capabilities and project management

The resource-based view of the firm (RBV, Barney, 1991) focuses on specific organizational resources and their capacity to confer competitive advantages, with the underlying assumption that an organization achieves a better competitive position if it owns and controls resources that are valuable, difficult to imitate, difficult to substitute, and rare. A dynamic capabilities view (Teece et al., 1997) extends the RBV by concentrating on capabilities, perceived as specific forms of unique organizational resources. A dynamic capability is "a learned and stable pattern of activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness" (Zollo and Winter, 2002, p. 340). Dynamic capabilities result from organizational learning mechanisms, such as experience accumulation, organizational routines and coordination, and the integration of processes, both internally and externally (Teece et al., 1997). Thus, their value is subject to the firm's ability to expand, develop, and leverage its capabilities.

But which capabilities might facilitate the development of products with environmental features? Ecological product design is not an easy task; it requires substantial know-how about materials, their impact on the natural environment, and the availability of potential substitutes (Johansson, 2002). This knowledge may reside both within and outside an organization and could be obtained or integrated through technological devices.

Discussing success factors for new product development, Brown and Eisenhardt (1995) stress the importance of actors and innovation processes. They propose that new product development is more successful if teams consist of members with different functional specializations, who have access to different types of information and knowledge. They also argue that customer involvement improves understanding of customer needs and expectations, which should increase the marketability of the resulting products. Finally, they assert that communication stimulates project performance: Better connections among new product team members and with outsiders lead to more successful new products, and technology can provide for such connections.

These insights, gained from traditional product development settings, may transfer to product ecodesign contexts. Organizations could benefit economically from their integration capabilities (cross-functional, customer, and technological), because EPD offers opportunities to redeploy, enhance, and leverage existing integration capabilities in a different context, such that it enhances the value contributions of these capabilities. *Integration* denotes unified control over successive or similar industrial processes (Flynn et al., 2010). For product design or manufacturing, it implies the degree to which a manufacturer strategically collaborates with supply chain partners and manages intra- and inter-organizational processes collaboratively to maximize product value for customers (Flynn et al., 2010; Frohlich and Westbrook, 2001). Integration requires a longer-term horizon, such that relationships are continuous and repeating rather than transactional. The ongoing collaborations increase mutual trust and information sharing, and entities involved in these relationships have strong incentives to resolve their conflicts (Ellram and Cooper, 1990). In addition, we use the term *manufacturing performance* to designate conventional dimensions such as cost efficiency, quality, and delivery, as addressed by operations management literature (Fugate et al., 2009; Miller and Roth, 1994; Skinner, 1966; Wheelwright and Hayes, 1985).