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Do design rules facilitate or complicate architectural innovation in innovation alliance networks?☆

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ABSTRACT

Architectural innovation is fundamental to the renewal of technological systems. However, it can be a real challenge to organize architectural innovation, all the more so when success hinges upon close collaboration with other firms that are responsible for different subsystems of the end product. This study examines the impact of product design rules and the degree of organizational coupling among innovation network partners on the performance of architectural innovation projects. Using data from 270 collaborative innovation networks in the United States, we found an inversely U-shaped relationship between the presence of design rules and architectural innovation performance. When a certain turning point is reached, dominant design rules have a pronounced net negative impact on the performance of collaborative architectural innovation projects. At the same time, our findings reveal that lead firms can alleviate this negative effect of strong design rules by selecting loosely coupled innovation partners. Accordingly, our findings suggest that the presence of design rules and the extent of partner coupling should be considered jointly when optimizing network configurations that focus on architectural innovation.

1. Introduction

In many industries, a company's survival depends on its ability to manage technological innovation. While a considerable number of innovations involve only changes within a particular module of a product or process, sometimes innovations can be architectural in nature, redefining the overall design of the product or process. An interesting case is provided by Shimano's gear shifting system. By redesigning four components – shifter, derailleur, freewheel, and chain – and changing the relationships between them, Shimano was able to develop the 'click-shifting' system that made it far easier for riders to tell when they had effectively shifted their gears. As a result of this architectural innovation, Shimano became, by far, the dominating firm supplying bicycle gear-shifting systems (Fixson and Park, 2008).

Compared to modular innovations, architectural innovations are more systemic by nature because they change the way in which subsystems are configured (Henderson and Clark, 1990). Architectural innovation may be necessary, for example, when well-defined interfaces among subsystems constrain firms from pursuing technological opportunities provided by new materials, improved production technologies, or a higher expected quality of integrated subsystems (Cacciatori and Jacobides, 2005). When a product architecture stabilizes and architectural understanding increases as, for example, in the air conditioning industry (Cabigiosu and Camuffo, 2012), a full set of design rules is likely to emerge (Baldwin and Clark, 2000; Baldwin and Clark, 2006; Henderson and Clark, 1990). Such design rules describe the *product architecture*, the *interfaces*, the *integration protocols* and the *testing standards* that will be used (p.77; Baldwin and Clark, 2000). Together, such design rules clarify the interactions across a product's subsystems. However, the literature is ambiguous on how the presence (and nature) of design rules affects the performance of architectural innovations where existing interfaces, related integration protocols and testing standards are being redefined.

☆ This paper is based on parts of the first author's doctoral dissertation submitted to the University of Twente, The Netherlands (Hofman, 2010).

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A clear set of design rules reduces the related need for ongoing communication and coordination among development team members when improving, or even redefining, subsystems (Baldwin and Clark, 2000; Henderson and Clark, 1990; Sanchez and Mahoney, 1996; Tiwana, 2008; Von Hippel, 1994). Design rules are likely to reduce ambiguity in technical communication by providing a shared technical vocabulary, which increases the companies' ability to discuss and coordinate changing linkages between subsystems (Argyres, 1999). Without design rules, it is difficult for partners to discuss such architectural changes. At the same time, when companies adhere too much to ex-ante defined design rules, this might impede their ability to fundamentally (re-)define and develop architectural innovations, since the considered problem-definition and solving space will be constrained by the mere presence of design rules. In their case study on four consecutive architectural innovations in the semiconductor industry, Henderson and Clark (1990) found that, although established firms invested heavily in the next product generation, success was limited. They argue that, once dominant design rules are established, departmental communication channels between internal component suppliers become structured around the existing product architecture. Therefore, established firms tend to overlook the technical changes that architectural innovations require due to information processing heuristics that are deeply rooted in the design rules of their existing products. This consistently resulted in low performance of the architectural innovations under study (Henderson and Clark, 1990).

In many industries, product design rules allowed for the rise of specialized component suppliers (Baldwin and Clark, 2000). Therefore, today, architectural innovation is further complicated because products often consist of subsystems that are supplied by different companies (Adner and Kapoor, 2010; Brusoni et al., 2001). This means that architectural innovations must be coordinated in a network of firms and across organizational boundaries, adding to the complexity of successfully developing such innovations. A number of studies focused on the organizational processes that facilitate the search for new and different product architectures in a network of partner alliances (Brusoni, 2005; Brusoni and Prencipe, 2006; Brusoni et al., 2001; Langlois, 2002). The influential case study of Brusoni et al. (2001) shows that lead firms should 'know more than they produce' to effectively coordinate architectural innovation in innovation alliance networks. They argue that, in multi-component, multi-technology products, the periodic introduction of new product architecture requires the coordination of change across organizational boundaries and technological fields. Such coordination is enabled by the lead firm that has to develop and renew its architectural knowledge about how new components are integrated into a coherent end product (Brusoni et al., 2001). For similar reasons, Adner and Kapoor (2010) argue, and empirically show, that a lead firm can benefit from early entry into a new product generation by progressing down the (architectural) learning curve in advance of its rivals, which is essential if the architectural innovation is to be brought successfully to market.

In these studies, less attention is paid to the characteristics of the network in which architectural innovation unfolds (Adner and Kapoor, 2010; Dhanaraj and Parkhe, 2006; Wolter and Veloso, 2008). Our study aims to address this void by analyzing whether and to what extent the characteristics of the network – involved in architectural innovation – contributes to its performance. More specifically, we investigate whether lead firms that initiate architectural innovation can mitigate the likely pronounced negative effects of design rules by selecting appropriate innovation network partners. We draw upon modular systems and social network theory to arrive at propositions on how the availability of design rules affects the performance of architectural innovation organized in networks, and how this relationship can be moderated by the degree of organizational coupling among network members. Our findings reveal an inverted U-shaped relationship between the presence of design rules and architectural innovation performance. At the same time, we note that the lead firm can compensate for the 'dark side' of design rules that are too strictly defined by selecting more loosely coupled partners. Accordingly, our study is the first to reveal that the effectiveness of architectural innovation hinges not only on the characteristics of the focal firm but also on the socio-cognitive characteristics of the network in which this type of innovation is being pursued. For practitioners, these findings imply that the effectiveness of architectural innovation can be steered by selecting more appropriate partners.

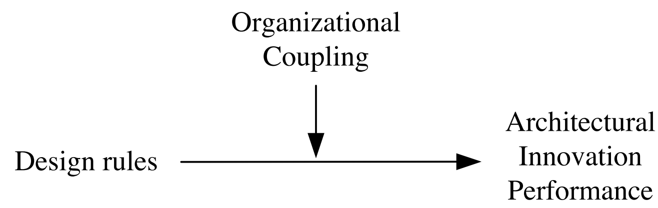

Fig. 1. Contingency model for collaborative architectural innovation projects.

This paper is organized as follows. We begin with an examination of how the presence and strength of design rules influence the performance of collaborative architectural innovation. Then, we explain how levels of organizational coupling among innovation network members may influence the impact of design rules on the performance of architectural innovations. Next, we explicate the research design and present the empirical results. Finally, we discuss the main theoretical and managerial implications of our findings, important limitations of our study and alternative avenues for future research.

2. Theoretical background and hypotheses

Fig. 1 summarizes this study's hypotheses. Our theoretical model assumes the presence of design rules (Baldwin and Clark, 2000) that affect the performance of architectural innovation and suggests that this relationship is contingent on the level of organizational coupling (Orton and Weick, 1990) among the involved innovation alliance network partners.

2.1. Architectural innovation

The performance of a technological system is dependent not only on the performance of constituent components but also on the extent to which they are compatible with one another (Garud et al., 2002; Schilling, 2000). Simon (1962, p. 468) explains that, because such multiple parts can interact in non-trivial ways, the system as a whole is greater than the sum of its individual parts. To improve the overall utility of technical systems, companies can optimize the inner working of major subsystems while leaving the design rules intact, or they can architecturally innovate. The concept of architectural innovation was proposed by Henderson and Clark (1990) who defined architectural innovation as innovations that '. . . change the way in which the components of a product are linked together, while leaving the core design concepts (and thus the basic knowledge underlying the components) untouched' (p.10). In contrast to incremental innovation, architectural innovation is more systemic in nature (Benner and Tushman, 2003; Smith and Tushman, 2005) and places a premium