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Grounding the “mirroring hypothesis”: Towards a general theory of organization design in New Product Development

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ABSTRACT

The similarity between product architecture and organization design has become known as the “mirroring hypothesis”. We present a theoretical model of new product development using the NK-model, in which we represent organization design with varying degrees of mirroring. The main result holds that perfectly mirroring organizations only perform well in designing products with many components and low complexity, while imperfectly mirroring organizations do better in designing product with few components and high complexity. Our theoretical model can inform future empirical research, which hitherto lacked a common representation framework for organization design.

1. Introduction

Ever since the topic of modularity emerged in management science and innovation studies (Henderson and Clark, 1990; Langlois and Robertson, 1992; Ulrich, 1995), a central hypothesis holds that a modular product architecture is likely to be reflected in a modular organization design (Sanchez and Mahoney, 1996; Baldwin and Clark, 2000). This hypothesis later became known as the ‘mirroring hypothesis’ (Colfer and Baldwin, 2016). Since the product architecture pre-specifies the design specifications to which modules have to adhere, each module can be developed and produced independently from the other modules. Hence, the product development and production process requires less coordination, allowing the firm to grant substantial autonomy to its divisions, or even to outsource module design and production to other companies. Reversely, more integrated product architectures would require more centralized organization design with few options for outsourcing.

Criticisms of the mirroring hypothesis exist, based on empirical evidence (Brusoni et al., 2001; Ernst, 2005; Frigant and Talbot, 2005; Cabigiosu and Camuffo, 2012; Furlan et al., 2014). One of the main critiques has been that product architectures are not necessarily stable, and hence co-evolve with organizational processes. At the same time, empirical evidence also supports the mirroring hypothesis for cases where product architectures remained fixed, even if most evidence is limited to the computer and software industries (Sosa et al., 2004; Hoetker, 2006; MacCormack et al., 2012; Baldwin et al., 2014).

Notwithstanding the insights gained from empirical studies, and the auxiliary hypotheses that followed from the original hypothesis, the mirroring hypothesis itself has remained underexplored theoretically. It seems self-evident that the organization design is directly related to the exact nature of interdependencies, given that human organizations primarily exist to deal with interdependencies (Langlois, 2002). More specifically, modular product architectures are expected to be reflected in modular organizations, a conjecture going back to Simon’s (1962) work on nearly decomposable systems. Hence, it seems that the intuitive appeal of the mirroring hypothesis may explain the lack of further theorizing.

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Given that the mirroring hypothesis lacks a precise theoretical foundation, further hypothesis-driven empirical research could benefit from a general theoretical framework. Such a framework could bring together and stimulate dialogue among current “supporters”, “opponents” and “contingents” of the mirroring hypothesis, as identified by [Sorkun and Furlan \(2017\)](#), under a single analytical umbrella. The model that follows is a first attempt to come to a model of mirroring between organization design and product architecture. Our model is a general model, in that it is not limited to modular architectures, but includes any architecture that can be expressed as a Design-Structure Matrix (DSM) ([Baldwin and Clark, 2000](#)). This allows us to understand, theoretically, whether the mirroring hypothesis is a general hypothesis, or one that is specific to a subset of product architectures. Consequently, this research is consistent with the call made by [Cabigiosu and Camuffo \(2012\)](#) for a shift from research focused on assessing the hypothesis’ mere existence to research focused on the conditions under which the hypothesis is valid.

Here, we go beyond solely focusing on modular designs, and ask the general question whether any organization design mirroring a product design would result in the development of the best design. To this end, we adopt the NK-model as first introduced in the social sciences by [Levinthal \(1997\)](#) and later adapted as a model of artefact evolution by [Frenken and Nuvolari \(2004\)](#). We supplement the standard NK-model with an organization design layer that determines the decision-making structure of agents. A perfect mirroring between the product and organization designs means that all interdependencies between the product’s components are reflected by collective decision-making structures at the organizational level. Following this definition, any other decision-making structure can then be expressed by their difference from the perfectly mirroring decision-making structure as the number of dependent components that are being ignored when a particular agent carries out a mutation. Hence, our model is a general model in which any organization design can be modelled as expressed by any directed communication network among organization members, hence going beyond existing models that reason solely from non-overlapping firm divisions ([Rivkin and Siggelkow, 2003, 2007](#); [Baumann, 2015](#)). The advantage is to avoid any strict assumptions about the level of technological decomposability: complex, near-decomposable or modular systems can be implemented within this modelling framework.

The model flexibility is particularly relevant to provide a more systematic perspective on New Product Development. We assume that deviations from perfect mirroring happen when the organization lacks technological knowledge about the new product in development (including the architecture of technological interdependences). Technological knowledge improves during the development process when alternative component technologies are implemented and their effects on the global product are compared. Given the myopic nature of search in our model, search processes do not necessarily end up in a local optimum in which single agents can no longer improve their individual fitness (Nash equilibrium). Instead, search may well continue endlessly, thus requiring a deadline in the organization to settle on a New Product Design, once the search has produced different prototypes that can be evaluated by comparison with each other. This is why we will compare the search result of different decision-making structures by measuring the overall fitness of the best product design ever found during a fixed time period. This implies that some agents, who could have improved their component’s performance by mutation of the best design, will be less satisfied by the final choice of design. We consider this a second relevant assessment criterion of an organizational structure, since the internal support and commitment to the new product design not just depends on some objective fitness criterion relevant to the firm as a whole, but also on the prestige that all individual agents experience for their contribution to the selected product design ([Guth and MacMillan, 1986](#)).

We proceed as follows. After a literature review in Section 2, we present the NK-model as a model of New Product Development (NPD) in Section 3. In Section 4, we extend the model by representing organization designs by the organization’s decision-making structure. In Section 5, then, we present simulation results and we end with a discussion about the theoretical, empirical and managerial implications of our work.

2. The mirroring hypothesis

The mirroring hypothesis emerged out of an older literature on modularity in the early 1990s ([Henderson and Clark, 1990](#); [Langlois and Robertson, 1992](#); [Ulrich, 1995](#)). One of the key hypotheses that has emerged from this literature holds that an organizational design is expected to mirror its product’s design ([Colfer and Baldwin, 2016](#); [MacCormack et al., 2012](#)). Hence, one would expect that the more modular the product of a firm, the more likely that this firm has a decentralized organization design, either in terms of having semi-autonomous departments each responsible for a module, or in terms of being a system integrator with supplier firms each producing a module.

Compared to more centralized forms of organizing production, a decentralized organization can have mainly two advantages ([Baldwin and Clark, 2000](#)). First, the overhead costs can be much lower as little explicit coordination is needed during the production process. Second, each module can be adapted to changing circumstances (e.g., prices, consumer tastes), without the need to re-design the whole product also known as inter-temporal economies of scope ([Helfat and Eisenhardt, 2004](#)).

The reduced coordination, however, generally come at a cost: (i) higher development costs due to the additional need of interface standardization ([Sanchez and Mahoney, 1996](#)); (ii) the risk of losing component-specific knowledge needed for effective outsourcing ([Takeishi, 2002](#)); (iii) lower overall performance as complementarities (“synergistic specificity”) between product components remain underexplored as strict interfaces do not allow so ([Schilling, 2000](#); [Fleming and Sorenson, 2001](#)); and (iv) the risk of getting locked into a product architecture and its accompanying organization design preventing firms to effectively develop radically new architectures ([Henderson and Clark, 1990](#); [Brusoni et al., 2001](#)). Hence, depending on the relative importance of costs and benefits, there is a theoretically-optimal level of modularity for each technology.

Apart from advantages in production, modularity also generates advantages in New Product Development (NPD). Indeed, the mirroring hypothesis was first and foremost a hypothesis about the design of NPD organizations. In its earliest formulation, also known as Conway’s Law, it was argued that “organizations which design systems (...) are constrained to produce designs which are

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