

'Closing the Loop' in an Architectural Perspective on Strategic Organizing

Towards a Reverse Mirroring Hypothesis

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'Closing the loop' in an architectural perspective on strategic organizing:

Towards a Reverse Mirroring Hypothesis

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Abstract

This paper elaborates important *systemic interrelationships* between firms' strategic choices of product architectures and organization architectures, and between firms' architectural choices and the industry structures and competitive/cooperative dynamics that emerge in an industry. We formalize a "*Reverse Mirroring Hypothesis*" suggesting that organizational architectures desired by firms influence their choices of product architectures. We embed firms' strategic architectural decisions in a co-evolutionary model linking product market evolution, firms' architectural choices, and industry evolution. We invoke both *transaction costs* and *capabilities* perspectives to suggest how firms' assessments of their relative potential for capturing *gains from specialization* versus *gains from trade* influence their strategic architectural choices. We develop concepts of *architectural commonality*, *architectural specificity*, *industry standard architectures*, and *firm-specific architectures* to analyze strategic implications of firms' architectural choices.

INTRODUCTION

In their paper on the influence of modular product architectures on market and organization strategies, Sanchez and Mahoney (1996) argued that 'products design organizations,' suggesting that the product architecture a firm uses will tend to be reflected in the organization architecture the firm adopts to develop, produce, and support its products. Subsequently labeled the 'mirroring hypothesis' by Colfer (2007) and formalized by Colfer and Baldwin (2010), numerous studies have found considerable empirical support for Sanchez and Mahoney's proposition. Colfer and Baldwin's (2010) review of 102 empirical studies, for example, found that the mirroring hypothesis was supported in 69% of all cases reviewed.¹

In a footnote in their 1996 paper, Sanchez and Mahoney (1996:fn.8, p.74) also suggested that widespread adoption of modular product architectures by firms in some industries appears to have led to the emergence of (in effect) *modular industry architectures* in which 'globally dispersed, loosely coupled organizations' can freely plug and play in developing, producing, assembling, and servicing the components used in an industry's modular product architectures.

Subsequent research has sought to clarify more generally how firms' choices of product architectures (and by implication, organization architectures) may lead to different kinds of competitive and cooperative inter-firm dynamics in an industry (Sanchez 2008, 2012; Furlan, Cabigiosos, and Camuffo, 2013). In addition to exploring the influences of modular *versus* non-modular product architectures on organizations and industries, for example, research has suggested that the extent of competitive versus cooperative interactions among firms in an industry may depend

¹ In a retrospective on their 1996 paper, Sanchez and Mahoney (2013) suggested several managerial and organizational factors that may explain why some firms do not adopt organization architectures that exactly mirror their product architectures. These include *cognitive factors* (Do managers realize the speed and flexibility advantages that can result from adopting a modular development process and corresponding modular organization design?), *risk and capability factors* (Are managers willing and able to lead the strategic organizational changes needed to implement modular development processes and modular organization designs?), and *organizational commitment and discipline factors* (Will development staff adhere to the principles of a modular development processes, especially with respect to conforming to the standardized interface specifications in a modular architecture?).

significantly on whether the architectures used in an industry are *open systems* in which many firms can participate or *closed systems* controlled by individual firms for their exclusive use (Schilling and Steensma 2001).

Research has also begun to consider the ways in which and the extent to which firms' choices of next-generation product architectures may be interlinked with—and thus influenced by—their current or desired organization structures and by the inter-firm dynamics in an industry. In an early study of Japanese auto industry supply chains, Sako (2003) observed that a firm's suppliers' capabilities and relationships appeared to influence the firm's choices of components—and thereby the component characteristics of the firm's product architectures. Sanchez (2008, 2012) suggested that managers' beliefs about current, emergent, and likely-to-emerge industry structures are likely to influence their choice of modular versus non-modular architectures and open-system versus closed-system architectures. Most recently, MacDuffie (2013: 13) has suggested that various 'context-specific antecedents' can influence the ways firms define modules in their architectures, noting that there may be a 'reverse causality' in the relation between product and organization designs.

A theoretically important implication of this stream of research is that the causal relationships between product architectures, organization architectures, and industry competitive and/or cooperative dynamics may not be unidirectional, but rather may be reciprocal and bi-directional—i.e., *systemic* in nature. In essence, this research has begun to suggest that firms' decisions about product architectures may be systemically intertwined with—and thus are unlikely to be made in isolation from—strategic concerns about a firm's organization architecture and how alternative organization architectures may affect the nature of the interactions a firm will have with other firms in its industry. Nevertheless, as Campagnolo and Camuffo (2010) have suggested, a theoretical framework that attempts to identify and reconcile the causal relationships between product architectures, organizational designs, and industrial production systems has yet to be put forward.

In this paper, we seek to extend and deepen the architectural perspective on firms' strategic organizing decisions by elaborating a set of *systemic*

interrelationships between firms' choices of product architectures and organization architectures, on the one hand, and between firms' architectural choices and the industry structures and inter-firm competitive and cooperative dynamics that emerge in an industry, on the other (Boisot and Sanchez 2010). To do so, we develop a general model from which we derive two broad propositions. First, our model suggests that firms' organization architectures do not follow unilaterally from firms' choices of product architectures, but rather that firms choose product and organization architectures in a *joint decision process*. Second, our model suggests that firms' strategic choices of product and organization architectures both influence and are influenced by the competitive and cooperative dynamics that currently exist in an industry—or that firms believe could emerge in an industry (Pitelis and Teece 2009).

To elaborate our model, we suggest that the influence of product architectures on organization architectures recognized in the mirroring hypothesis needs to be complemented by a *Reverse Mirroring Hypothesis* ('RMH'), which essentially holds that the organizational architectures that firms believe may be possible and advantageous to adopt in an industry will influence (i.e., be reflected in) their choices of product architectures. As we suggest in **Figure 1**, the RMH 'closes the loop' to provide a more complete representation of what we suggest are key systemic interdependencies in firms' strategic decisions about their product and organization architectures.

<<<--- Insert **FIGURE 1** Here --->>>

We then embed our representation of a firm's joint decision-making about product and organization architectures in a co-evolutionary model linking product market evolution (represented by emergent market opportunities served by entrepreneurial action), firms' choices of product architectures and organization architectures, and industry evolution (represented by changes in the architectures used in an industry and by associated changes in competitive and cooperative inter-firm dynamics), as illustrated in **Figure 2**.

<<<---INSERT FIGURE 2 HERE--->>>

The architectural choice process at the heart of our co-evolutionary model suggests that a firm's joint choice of product and organization architectures will be driven in important part by its assessments of the relative potential for capturing *gains from specialization* versus *gains from trade* in alternative pairings of product and organization architectures judged to be feasible within the firm's evolving market and industry contexts (Jacobides, 2005; Jacobides and Billinger, 2006; Sanchez 2008, 2012). Our model also suggests that in the aggregate, firms' weighing of potential gains from specialization and from trade—and their resulting decisions about the product and organization architectures it would be most advantageous to adopt—drives the strategic evolution of the architectures used in an industry and the competitive and cooperative industry dynamics enabled by those architectures.

Our discussion is developed in the following way.

We first put forward some essential concepts for distinguishing different kinds of product and organization architectures that enable different kinds of competitive and cooperative dynamics in an industry. We introduce concepts of *architectural commonality* and *architectural specificity* that we then use to derive concepts of *industry standard architectures* and *firm-specific architectures*.

These essentially technical representations of the architectures used in an industry enable our strategic analysis of how firms' architectural choices are likely to influence inter-firm competitive and cooperative dynamics in an industry. We identify four fundamental combinations of architectural choices and resulting industry dynamics available to firms, each of which is likely to lead to different kinds of competitive and cooperative inter-firm dynamics.

We then suggest how the industry architecture contexts we identify offer different potentials for achieving important strategic advantages. We first draw on transaction costs economics to suggest how firms' choices of architectures are likely to affect both their *ex ante* and *ex post transaction costs* (Langlois, 2006; Baldwin 2008). We then draw on the capabilities perspective in strategy to consider how a

firm's assessments of its relative potential for capturing gains from specialization versus gains from trade is likely to influence its strategic choices of product and organization architectures, and thereby the extent to which its interactions with other firms in its industry are likely to be competitive or cooperative in nature (Jacobides, 2005; Jacobides and Billinger, 2006; Sanchez, 2008, 2012).

We then draw on these analyses to elaborate the essential theoretical rationale motivating our *Reverse Mirroring Hypothesis* and our co-evolutionary model linking product market evolution, firms' architecture choices, and industry evolution.

We conclude by suggesting what we believe are some of the most important contributions that our analysis of the influence of product and organization architectures on firm strategies and industry dynamics brings to both strategy theory and to theories of economic organizing.

TYPES OF ARCHITECTURES

We begin our analysis by distinguishing kinds of product and organization architectures that are likely to have different influences on the extent to which an industry will be characterized by competitive or cooperative inter-firm dynamics. We first introduce the concepts of *architectural commonality* and *architectural specificity*, which we then use to distinguish whether a firm is using a *firm-specific architecture* or an *industry standard architecture*. Our subsequent discussion uses these essentially technical distinctions among architectures to suggest how and why firms' architectural choices influence inter-firm competitive and cooperative dynamics in an industry.

Product and organization architectures

We base our analyses on the established concept of *product architecture* defined as (i) the decomposition of a product design into functional components, and (ii) the interfaces between functional components that determine how the components will interact when they function together in a product design (Sanchez and Mahoney

1996; Baldwin and Clark, 2000; Sanchez 2000; Schilling, 2000). We also adopt an analogous concept of *organization architecture* defined as (i) the decomposition of an organization design into functional components (organizational units that perform various functions), and (ii) the interfaces between functional units that determine how the units interact when they function together in an organization design (Sah and Stiglitz, 1986; Hoetker 2006; Sanchez and Mahoney, 2013).

In our analyses, we assume that both the Mirroring Hypothesis and our Reverse Mirroring Hypothesis hold—i.e., that a firm will seek to achieve close alignment of its product and organization architectures (Sanchez and Mahoney 1996; Baldwin 2008; Colfer and Baldwin 2010). For brevity, we therefore often use the term ‘architectures’ to refer jointly to a firm's product *and* organization architectures, which in our analysis we assume will ‘mirror’ each other to a significant extent.²

Architectural commonality and architectural specificity

The product and organization architectures that various firms adopt may differ in the ways they have been *strategically partitioned* into functional components, and in the ways that interfaces have been specified to govern the interactions between the functional components in an architecture (Sanchez, 1999; Baldwin and Clark, 2000; Brusoni, Principe, and Pavitt, 2001; Baldwin, 2008). For the purposes of our analyses, we distinguish the architectures firms adopt in an industry by the extent to which they share significant architectural commonalities or exhibit significant architectural specificities in the components and interfaces they use.

² The rationale for the mirroring hypothesis is twofold: Garud and Kumaraswamy (1995: 98) suggested broadly that an organization system design must ‘parallel’ a technological system design in order to achieve *economies of substitution*. Sanchez and Mahoney (1996) then suggested that the information structure provided by the interfaces in a modular architecture may provide *embedded coordination* for a firm's development activities, thereby improving managerial and organizational efficiencies. Sanchez (2012) has drawn on these two perspectives to propose a *principle of architectural isomorphism* that holds that firms whose product and organization architectures are aligned will be able to achieve inherently *more efficient*—i.e., *lower cost and faster*—development, production, and after-service processes than firms whose product and organization architectures are not aligned.

Architectural commonality refers to the property of architectures that have been strategically partitioned into similar kinds of functional components and that have adopted similar interface specifications for governing the interactions of their functional components. Firms that have adopted product architectures with high levels of commonality may to that extent provide each other with components that can 'plug and play' in each other's product architectures (Sanchez, 2008, 2012; Cabigiosu and Camuffo, 2012). Firms that have adopted product and organization architectures with high levels of commonality will also to that extent be engaged in similar kinds of development, production, customer support, and other functional activities. High levels of product and organization architectural commonality among firms enable those firms to more readily provide product components and development, production, and service activities to each other, and to otherwise engage in collaborative activities that can 'plug and play' in each others' organization architectures and processes.

By contrast, *architectural specificity* refers to the property of architectures that have been strategically partitioned into kinds of components that are functionally different from those used in other firms' architectures and/or that have adopted interface specifications for their components that are not compatible with the interface specifications used in other firms' architectures. Firms that have adopted product architectures with high levels of specificity will to that extent be committed to using components that cannot 'plug and play' in other firms' product architectures and that cannot readily be sourced from other firms, owing to their functional and/or interface differences (Sanchez, 2008; MacDuffie, 2013). For the same reason, firms that have adopted organization architectures with high levels of specificity will to that extent not be readily able to provide or receive development, production, and service activities to or from other firms or to engage in collaborative activities, because their organization functions are not aligned with those used in other firms' organization architectures and processes.³

³ Baldwin (2008) characterizes the lack of such interactions between firms with architectures that are highly specific as creating 'transaction-free zones.' Note also the architectural characteristics we describe here are sometimes referred to by various other

Industry standard architectures and firm-specific architectures

The architectural choices that firms make will result in individual firms adopting what we henceforward refer to as an *industry standard architecture* or a *firm-specific architecture*. As we suggest below, the two kinds of architectures are likely to differ significantly in their system properties and in the way in which modularity is likely to be used.

Industry standard architectures (ISAs)

When at least two firms in an industry adopt product and organization architectures that have significant architectural commonality and are therefore technically able to engage in efficient exchanges of product components and organization activities, they create what we refer to as an *industry standard architecture* (ISA).⁴ Given this conceptualization, a given industry may include multiple ISAs competing to provide similar kinds of (architecturally distinct) products to the same customers or to different subgroups of customers.

In our framework, an ISA may be an *open system* in which any interested firms may participate, or a *closed system* controlled by a single firm or group of firms that decide which firms may participate in the ISA.⁵

terms in the literature. Architectures with high levels of commonality, for example, have been referred to as *platforms* (e.g., West, 2003; Boudreau, 2010), while architectures with high levels of specificity have been referred to as architectures with 'unique complementarities' (Argyres and Zinger, 2012).

⁴ An ISA is therefore likely to incorporate many of the ingredients of an 'industry recipe' (Spender, 1989) or 'template' (Jacobides, Knudsen, and Augier, 2006) for competing in an industry.

⁵ There are both technical and legal aspects to open-system and closed-system ISAs in this context. To participate in either an open-system or closed-system ISA, firms must have an adequate technical understanding of the way an architecture is partitioned into functional components and of the interfaces that enable the components to function together as a system. The legal aspect of open-system or closed-system ISAs concerns intellectual property rights (IPRs) in designs of components and interfaces. In an open-system ISA, component designs and interfaces are either not protected by IPRs or can be licensed on acceptable terms from the holder of relevant IPRs. In a closed-system ISA, the firm or firms controlling the ISA may use secrecy (especially with respect to interface specifications) or explicit IPRs to control participation in the ISA, typically by licensing other firms to use key

When either an open-system or closed-system ISA is also modular, firms that participate in the ISA may use the modularity property of the architecture as a 'platform' for exchanging a range of architecturally compatible product component variations and organizational activities that can readily 'plug and play' in the ISA they share. Exchanges of components and activities among firms using a modular ISA may enable them to configure product variations and rapidly upgrade products as new and higher-performing component variations are developed and exchanged within the ISA (Garud and Kumaraswamy, 1995; Sanchez 1995, 2008; Sanderson and Uzumeri, 1996). Use of standard 'common components' by firms using the ISA may also lead to economies of scale that lower component costs (Sanchez, 2008).

An ISA may be created by design—through explicit collaborations by firms—or may emerge in an industry as some firms independently converge towards a common architecture that they perceive to be the most advantageous to adopt in their industry (Baldwin and Clark, 1997; Jacobides, Knudsen, and Augier, 2006; Boisot and Sanchez, 2010).⁶

Firm-specific architectures (FSAs)

When a firm adopts an architecture with substantial architectural specificity, it essentially commits to using an architecture that does not enable ready exchanges of product components and organization activities with other firms. We refer to

component designs or interfaces used in the ISA. To meet our definition of an ISA, a closed-system ISA must allow the participation of at least two firms. In practice, firms that control an ISA may solicit the participation of many firms in order to gain the benefits of an open-system ISA while maintaining control over access to the ISA (Sanchez and Collins, 2001).

⁶ In the latter case, the emergence of an ISA would be analogous to Abernathy and Clark's (1985) notion of the emergence of a *dominant design* in an industry. However, Abernathy and Clark's dominant design concept primarily refers to a prevalent arrangement of components in a product design (which corresponds to our concept of the *strategic partitioning* of a design), while in our architectural framework the emergence of an ISA would also involve the emergence of *widely used interfaces* between components. Garud and Kumaraswamy (1995) suggest that positive network externalities motivate such emergent processes in industries. See Sanchez and Heene (2004, p. 139–143) for an elaboration of the incentives typically driving the emergence of standard types of components (i.e., common approaches to strategic partitioning) and the emergence of standard interface specifications in the evolution of an industry.

such a 'stand alone' architecture as a *firm-specific architecture* (FSA). An FSA is therefore likely to be a *closed-system* architecture controlled by a single firm for its exclusive commercial use in order to appropriate any rents to be derived from use of the FSA.

A firm may nevertheless choose to make its closed-system FSA modular in order to obtain the benefits of configuring greater product variety, more rapid upgrading of components, or lower costs for common components used across product variations (Sanchez, 1995, 2008; Worren, Moore, and Cardona, 2002; Kotha and Srikanth, 2013). It may then undertake to develop component variations for its FSA exclusively through its own internal capabilities, or it may seek to subcontract with other firms for development, production, or support services. In the latter instance, however, a firm using an FSA is likely to face significant development and production set-up costs from subcontractors because of the idiosyncratic nature of the functional components and interfaces used in its FSA. It may also face significant challenges and costs in trying to coordinate development and other activities with organizations whose strategic partitioning of these activities differs from its own.

INFLUENCE OF ARCHITECTURES ON INTER-FIRM COMPETITION AND COOPERATION

Traditional views of strategic interactions among firms in an industry tend to focus on competitive interactions between firms in product markets. The architectural perspective that we develop here, however, suggests that firms may be engaged in a more fundamental form of strategizing about their interactions with other firms—a process that in the first instance involves firms' choices of product and organization architectures that subsequently lead to the formation of alternative industry systems for creating and providing products to a market.

Within this perspective, an individual firm's most basic strategic choices are (i) whether to compete with a stand-alone, closed-system FSA or with an open-system ISA that can be used by other firms, and (ii) whether its chosen FSA or ISA

should be modular or non-modular. As we explain in this section, the architectural choices that a firm makes in these two regards will largely determine the extent to which its various interactions with other firms in its industry are likely to be competitive or cooperative.

The open-system versus closed-system and modular versus non-modular properties of firm architectures suggest that a firm's architectural choices are likely to commit it to one of four distinct kinds of competitive and cooperative inter-firm interactions in its industry.⁷ These four types of architecture-influenced inter-firm interactions are summarized in **Figure 3**.

<<<<<< Insert **FIGURE 3** Here >>>>>>

Adopting a closed-system FSA implies that the firm controlling and using the FSA will engage in largely competitive interactions with other firms in its industry, relying on its own internal capabilities and on licensed subcontracting to create components and support activities for its products. Modularity may also be used in the FSA if the controlling firm intends to develop component variations in order to configure product variations and upgrade product performance. If the firm does not intend to introduce many product variations or frequent upgrades, it may choose to use a non-modular FSA.

Adopting an open-system ISA, however, makes it easier and more efficient for a firm to engage in cooperative exchanges of components and activities with other firms using the same ISA. In particular, a modular ISA can serve as a 'platform' for a network of participating firms to actively develop and exchange component variations in order to increase product variety and to upgrade product performance, as well as lower product costs through use of common components. When the need for product variety and upgrading is low, use of a non-modular ISA may

⁷ In our representation of 'upstream' interactions between firms prior to product market competition, we adopt a Porterian view of contracting for components or services by a firm controlling an FSA and characterize such interactions as essentially competitive interactions between buyer and supplier (Porter, 1980).

nevertheless enable firms to exchange industry standard components (e.g., replacement parts) and services among participating firms.

In effect, the architectural perspective we develop here suggests that a firm's strategic choice of architecture is not just a choice between alternative product architectures for attracting customers to its final products. It is also a choice between alternative architecture-enabled *industry systems* for engaging suppliers, development partners, and other industry participants in exchanges of components and activities in composing the firm's value-creation activities within its industry (Jacobides, 2005; Fujimoto, 2007; Langlois and Gazarelli, 2008; Sanchez, 2008).

In the following sections, we extend this architectural perspective on firms' strategic organizing decisions by suggesting how a firm's choice of ISA versus FSA is likely to impact its *ex ante and ex post transaction costs* in its interactions with other firms. We also suggest how heterogeneous capabilities across firms in an industry create different potentials for firms to capture *gains from specialization versus gains from trade* through use of either an ISA or an FSA. We then combine our transaction costs and capabilities perspectives on inter-firm interactions to elaborate some further strategic concerns that are likely to drive a firm's choice of product and organization architecture. We also draw on these two perspectives to further elaborate the strategic influences that firms' collective architectural choices are likely to have on the evolution of product markets and industries, as suggested by our general model in Figure 2.

ARCHITECTURES AND TRANSACTION COSTS

We now consider some fundamental ways in which use of an ISA versus an FSA can affect the transaction costs a firm is likely to face in undertaking exchanges of components and activities with other firms in its industry. We consider the impacts of a firm's use of an ISA versus an FSA on (i) *ex ante and ex post transaction costs* generally, and (ii) on asset specificity, incomplete contracting, opportunism, and small numbers bargaining in particular.

***Ex ante* and *ex post* transactions costs**

Broadly construed, transaction cost economics frames ‘the problem of economic organization as a problem of contracting’ in which transaction costs represent all the costs associated with contracting – i.e., with market transactions—in organizing economic activity (Williamson 1985: 19). Transaction cost economics (TCE) generally assumes that markets offer the most efficient approach to organizing economic activity, and that decisions to internalize and hierarchically coordinate an activity will be made only when the transaction costs associated with contracting for a given activity exceed the full costs of internally performing the activity.⁸

TCE recognizes both *ex ante* and *ex post* transaction costs associated with contracting. In classical TCE, *ex ante* transaction costs represent the ‘costs of drafting, negotiating, and safeguarding an agreement’ (Williamson 1985: 20). *Ex post* costs include (i) the costs of ‘maladaptation...when transactions drift out of alignment,’ (ii) ‘haggling costs incurred if bilateral efforts are made to correct *ex post* misalignments,’ (iii) ‘the set-up and running costs associated with the governance structures to which disputes are referred,’ and (iv) ‘the bonding costs of effecting secure commitments’ (Williamson 1985: 21).

Both *ex ante* and *ex post* transaction costs are influenced by the three ‘critical dimensions’ of economic transactions: uncertainty, frequency, and asset specificity (Williamson, 1979: 239; Langlois, 2006: 1390; Carter and Hodgson, 2006; Macher and Richman, 2008). Uncertainty increases the *ex ante* costs of trying to write adequate contracts and results in some degree of ‘incompleteness’ in a contract (Hart, 1995; Baldwin, 2008). Any resulting contractual incompleteness may lead to *ex post* costs arising from unforeseen contingencies that may require further negotiations or may incur ‘hold up’ costs if transaction partners engage in opportunistic behavior. The frequency of transactions acts as a multiplier on the *ex*

⁸ As Williamson (1985: 87) notes, ‘only as market-mediated contracts break down are transactions....removed from markets and organized internally. The presumption that ‘in the beginning there were markets’ informs this perspective.’ In classical TCE the ‘full costs of internally performing an activity’ referred to above include the costs of production and the opportunity costs inherent in the (presumed) loss of efficiency when an activity is organized internally instead of through markets.

post transactions costs associated with each contract a firm makes. Asset specificity creates a risk that any specific-use assets on which a contracting firm's processes depend may not be available (or available on pre-agreed terms) when needed by the firm.

Influence of architectures on *ex ante* and *ex post* transaction costs

How firms' architectural choices affect their *ex ante* versus *ex post* transactions costs is a rather recent concern in transaction cost economics (Langlois, 2006; Santos Abrunhosa, and Costa 2006; Baldwin, 2008). In analyzing the effects of modularity on transactions costs, Baldwin (2008:156) suggests that the concepts of *ex ante* and *ex post* transactions costs can be further elaborated by distinguishing certain kinds of architecture-related 'mundane transactions costs' that can be incurred *ex ante* in order to reduce *ex post* 'opportunistic transactions costs.'

Baldwin (2008: 156) specifically characterizes the costs of creating modular architectures as an *ex ante* mundane transaction cost that reduces *ex post* opportunistic transaction costs involved in developing and producing products. *Ex post* transaction costs can be reduced, for example, by *ex ante* defining specific kinds of modular components to be transacted for and specific measures for assessing component quality and performance, thereby enabling use of the market price mechanism in *ex post* transactions for components. Langlois (2006) further characterizes the creation of legal, technical, and organizational standards as mundane transaction costs that help to reduce *ex post* opportunistic transaction costs. For example, *ex post* transaction costs can be reduced when firms can use standard technical specifications, standard contracts, and standard contracting and monitoring procedures for inter-firm exchanges within a modular ISA regime.

We extend this line of reasoning to suggest that a fundamental dimension of the strategic organizing task of strategic managers is considering which kinds of architectures offer their firm *ex post* transaction costs that are attractive relative to the *ex ante* transaction costs the firm would have to incur in order to create and use a given architecture.

Choosing an FSA, on the one hand, may give a firm strategic benefits resulting from exclusive control and use of its architecture, for example, but it is also a strategic decision to incur full development costs for a firm-specific architecture, resulting in potentially high *ex ante* mundane transactions costs and a 'normal' level of *ex post* opportunism transaction costs (Baldwin 2008).⁹ If a firm also invests in the *ex ante* transaction costs of creating a well-defined modular FSA, which may include proprietary modular component designs and interface specifications protected by IPRs, it may realize lower *ex post* development costs in creating product variations and upgrades.¹⁰

Choosing an open-system ISA may take one of two forms: (i) a firm may decide to adopt and participate in an emergent or existing ISA; (ii) or a firm may take the lead in creating an architecture that it hopes will attract the collaboration of other firms interested in developing and using an ISA. To the extent that firms share the costs of developing a new ISA and compatible components, both adopting and creating an ISA are likely to result in reduced *ex ante* transaction costs (of development) to individual firms participating in the ISA compared to the *ex ante* transaction costs incurred by a single firm in developing its own FSA.¹¹

Further, recalling Langlois' (2006) and Baldwin's (2008) arguments that *ex ante* costs of creating modular architectures may significantly reduce several kinds of *ex post* transaction costs, and recalling our argument that use of a modular ISA may enable firms to engage in cooperative interactions that lower both the costs of developing the ISA and the costs of components used in the ISA, we suggest that participation in a modular ISA may reduce *both ex ante* and *ex post* transaction costs for firms in an industry. To the extent that modular ISAs enable significant

⁹ For example, a firm creating an FSA may incur significant *ex ante* transaction costs to establish IPRs that can prevent other firms from using its FSA *ex post*, but it would still have to incur 'normal' *ex post* transactions costs to defend its IPRs and its FSA.

¹⁰ This expectation corresponds to MacDuffie's (2013) observation that intensive coordination and communication activities are likely to precede the emergence of modular architectures and standardized interfaces—which we suggest would likely be the case in both modular FSA and modular ISA contexts.

¹¹ We also note that firms deciding to adopt an existing ISA developed by another firm may be able to substitute *ex post* variable costs of licensing IPRs from the developing firm for *ex ante* sunk costs of developing its own FSA.

reductions of *ex ante* and *ex post* transaction costs compared to use of FSAs or non-modular ISAs, we would expect that any ISAs that emerge in an industry are likely to be modular, and that adoption of modular ISAs will be increasingly common in industries where significant reductions of *ex ante* and *ex post* transaction costs are obtainable, *ceteris paribus* (Sanchez, 2003; Baldwin, 2008).¹²

Influence of architectures on asset specificity, incomplete contracting, opportunism, and small numbers bargaining

A firm's *ex ante* and *ex post* transactions costs may depend substantially on the kinds of assets that must be put in place in order for a firm to develop and use an architecture (Hoetker, 2006; Fixson and Park, 2008). In this regard, Williamson (1985: 30-32) suggests that the most critical challenges in economic organizing arise 'when bounded rationality, opportunism, and asset specificity are joined.'

Bounded rationality imposes limits on the abilities of contracting parties to imagine and address all possible contingencies in a contract (Simon 1954). In such cases, the bounded rationality of transacting parties (coupled with irreducible uncertainties about future contingencies) results in contracts for ordering market transactions that are incomplete to some extent, and sometimes to a very large extent (Arrow 1974; Hart 1995).

Traditional TCE is especially concerned when incomplete contracts for ordering transactions that depend on *specific-use assets* give rise to opportunities for a transacting party to engage in *ex post* opportunistic behavior or 'hold up.'¹³ When a firm contracts for use of a transacting party's specific-use assets, and those assets cannot easily be replaced because there will be few or no alternative transactions partners in the marketplace ('small numbers bargaining'), an

¹² This approach to evaluating transaction costs associated with architectures in strategic organizing is consistent with Williamson's (1985: 21) observation that *ex ante* and *ex post* contracting costs are interdependent and 'must be addressed simultaneously rather than sequentially.'

¹³ Williamson (1985:30) succinctly characterizes *opportunism* as 'self-interest seeking with guile.'

opportunistic transaction partner may impose substantial *ex post* transactions costs on its hapless transaction partner.

The use of an ISA and especially a modular ISA may significantly change this set of convergent factors that create concerns about *ex-post* opportunism arising from specific-use assets. While an ISA may require the use of assets that are specific to a given *type* of transaction within an architecture—e.g., development or production of a given type of component or activity that is specific to a given ISA—the threat of *ex post* opportunism in contracting with a supplier for use of its asset may be reduced to the extent that other firms participating in the ISA have a similar kind of specific-use asset. In effect, if an ISA attracts a significant number of firms as developers and producers of components and activities compatible with the ISA, a market may form around the ISA that mitigates the problem of small numbers bargaining, even when development and use of an ISA involves specific-use assets. The formation of a market for components and activities within an ISA regime may therefore eliminate or substantially reduce the *ex post* costs of opportunism associated with uncertainties about a firm's ability to obtain the services of a current supplier's specific-use assets in the future.

GAINS FROM SPECIALIZATION AND GAINS FROM TRADE

To complement our transaction costs perspective on architectural choice, we now consider how a firm's choice of architecture may also affect its ability to *capture value* through transactions undertaken within an architectural regime (Zajac and Olsen 1993). We adopt a capabilities perspective to suggest how a firm's choice of FSA or ISA will affect its ability to capture *gains from specialization* versus *gains from trade* (Jacobides, 2005; Boudreau, 2010).

Gains from specialization and trade

Economic theory has long recognized that firms that specialize in a particular productive activity may 'deepen their expertise' in ways that result in lower costs or better quality, thus realizing 'gains from specialization' in productive processes

(Smith 1981). When at least some firms specialize in the various technologically separable activities that constitute an overall productive process, other firms may realize 'gains from trade' with specialist firms by obtaining lower-cost and/or higher-quality components that enable them to offer more successful and profitable final products (Stigler and Sherwin, 1985; Madhok, 2002; Jacobides, 2005). The globally dispersed value chains in which many firms today produce, sell, and buy components suggest that at least some firms do simultaneously seek both gains from specialization and gains from trade (McDermott, Mudambi, and Parente, 2013).

Traditional TCE also recognizes the possibility of obtaining gains from both specialization and gains from trade. Given its traditional focus on costs and inter-firm contracts, classical TCE generally represents such gains as resulting in lower costs for inputs when a firm sources an input from another firm in the context of *unilateral trade* (i.e., conventional buyer-seller supply arrangements). TCE tends to have a more limited view of possibilities for realizing cost savings, quality improvements, and other forms of mutual gains in the context of *bilateral exchanges* between firms (Williamson 1985: 193-195). As we suggest below, the potential for capturing gains from specialization and trade through bilateral exchange may be significant, but is likely to vary considerably depending on whether a firm is using an FSA or an ISA, in large part because of the differences in appropriability regimes usually associated with the two kinds of architectures (Teece, 1986).

Gains from specialization and trade in an FSA context

A strategic choice to adopt an FSA is likely to be driven by a firm's belief that it can best succeed by using its own specialized capabilities to develop and produce products. A firm that adopts an FSA is therefore likely to use significant vertical integration of activities to develop and supply key components for its FSA (Klein, Crawford, and Alchian, 1978), though the firm may also engage in subcontracting for development and production of components in which it believes it does not have an

advantage. In effect, when a firm chooses to create and use an FSA, it is in important respects choosing to engage in traditional forms of 'atomistic,' stand-alone, Porterian competition with other firms in its industry (Porter, 1980). Value capture must then be sought in the form of gains from specialization that are realized through sales of the products made possible by its specialized capabilities.

Gains from specialization and trade in an ISA context

The strategic partitioning of an ISA into well-defined and technically stable types of components and interfaces offers opportunities for firms to specialize in specific types of product components and process activities used within the ISA. Because a current ISA offers a relatively defined and predictable technical environment for developing and exchanging ISA-compatible components and activities, ISAs often attract the participation of firms whose capabilities give them comparative advantages in developing and/or producing specific kinds of components used in an ISA (Hunt and Morgan, 1995; Galvin and Morkel, 2001; Jacobides, 2005; Sanchez, 2008). Both component specialists and assembler firms may realize gains from specialization and trade when this occurs.

Component specialists participating in an ISA may capture gains from specialization in the form of profits earned by selling components (i) in which they have cost advantages (relative to internalized production by non-specialist firms) realized by consolidating demand for their type of ISA-compatible component and achieving scale economies, and/or (ii) in which they use their deep expertise to develop and produce high quality ISA components that command higher prices than components offered by non-specialist firms. Such firms may also seek to capture gains from their specialization by collecting royalties on components licensed for production or use by other ISA firms, and/or by selling their own versions of products that incorporate their own components that confer cost or quality advantages.

When an ISA attracts firms that are specialists in various product and process components, assembler firms that configure products from ISA-compatible components sourced from specialist firms may realize significant gains from trade

in several ways. An assembler firm may realize gains from trade in the form of lower-cost components sourced from specialist firms that have consolidated demand to achieve economies of scale beyond those which the assembler firm could hope to achieve. An assembler firm that sources high quality components from specialist firms may also improve the attractiveness of its products, thereby enabling the firm to realize gains from trade by obtaining higher prices for superior products (Zajac and Olsen, 1993). In addition, when an assembler firm participates in a modular ISA, the firm may realize further gains from trade by sourcing a range of modular component variations to configure a broader range of product variations and by sourcing leading-edge components to upgrade the performance levels of its products. Both uses of components sourced from specialist firms may enhance the market appeal of its products, increase the prices the firm can obtain for its products, and thereby realize gains from trade in the form of increased profits (Sanchez, 1995; Sanderson and Uzumeri, 1997).

Both component specialist and assembler firms may benefit from a number of important *architectural externalities* created by ISAs (Sanchez, 2008; Boudreau, 2010).¹⁴ On the supply side, the well-defined functional structure and interface specifications of an ISA reduce the technical information search and processing costs for firms that are interested in entering an industry and need to learn the technical basis for products in the industry. ISAs may also incorporate technical standards that reduce the uncertainties and lower the costs of specifying, designing, testing, and maintaining products in an industry. ISAs may also encourage the establishment of an infrastructure of firms to service and repair products configured within an ISA and, when widely used, may stimulate the supply of engineers and technicians who can design and service ISA-compatible products (Sanchez, 2000; Funk, 2008).

On the demand side, ISAs may spawn performance standards that help customers to specify desired levels of quality and reliability and enable market comparisons of alternative ISA products. The increased scale of production of ISA-

¹⁴ Some of these architectural externalities may contribute to reduced *ex ante* and *ex post* transaction costs in ways not previously suggested by Langlois (2006) and Baldwin (2008).

compatible components and products (compared to most FSAs) may lower initial product costs, replacement parts and components, and maintenance and repair costs. When an ISA has attracted various assemblers who compete in the marketplace for final products configured within the ISA, customers may also avoid the 'lock-in' that use of products based on an individual firm's FSA would entail (Arthur 1994). All of these ISA-derived or ISA-enabled externalities may help to increase market acceptance of products leveraged from an ISA and thereby contribute to market formation and growth, which further contributes to the realization of gains from specialization and trade by firms using the ISA.

The use of an ISA by a number of firms in an industry often gives rise to significant levels of 'coopetition' among rivals – typically in the form of cooperation in upstream supply arrangements for development and supply of ISA-compatible components and activities among firms that are also downstream competitors in final products configured from the ISA architecture (Nalebuff and Brandenburger, 1996; Sanchez, 2008; Gnyawali, He, and Madhavan, 2006). While some firms may have special capabilities that are relevant only to specific components, other firms (especially large firms) may have both special capabilities relevant to one or more components and general capabilities useful to a producer and marketer of final products. These firms may—and often do—decide that they have comparative advantages in developing and producing specific components that make it possible to capture gains from specialization by supplying the components both to themselves and to other firms—thereby enabling opportunities for dual-distribution strategies (Safizadeh, Field, and Ritzman, 2008).¹⁵

¹⁵ For example, Philips, Sony, Matsushita, and other major consumer electronics firms have business units that sell components for consumer electronics products to other industry participants as well as to their own final-product business units. This form of coopetition has become increasingly common in automotive, telecommunications, financial services, and many other industries (Sanchez, 2008).

REVERSE MIRRORING HYPOTHESIS

We now draw on our foregoing analyses to elaborate the essential theoretical rationale motivating our *Reverse Mirroring Hypothesis* (see Figure 1), which we now state formally as follows:

Reverse Mirroring Hypothesis:

The organizational architectures that a firm believes may be possible and advantageous to adopt in an industry will influence the firm to choose a product architecture that is best aligned with the organization architecture the firm believes will enable it to capture the greatest net gains from specialization and trade—inclusive of both ex ante and ex post transactions costs.

Most fundamentally, our discussion leading up to the RMH has suggested that while a firm's choice of product architecture clearly determines *what products* a firm will be able to bring to market, the product and organization architecture it chooses will also largely determine *what resources and processes* a firm will be able to access in creating, producing, and supporting its products. Choosing to create a stand-alone FSA, for example, is essentially a decision to rely on the firm's own capabilities to create and use an idiosyncratic product architecture to compete against other firms. Choosing to create an ISA in which other firms may participate, on the other hand, is a decision to adopt a platform for cooperating with other firms and to draw on their resources and capabilities in bringing the firm's products to market.

Because the resources and capabilities a firm can readily access through its organization architecture may substantially influence the kind of products a firm can contemplate bringing to market, we suggest that a firm's selection of product architecture and organization architectures will be undertaken in a *joint decision process*. Hence, as Figure 1 suggests, the influence of product architectures on organization architectures suggested by the Mirroring Hypothesis needs to be complemented by a reciprocating influence of potential organization architectures

on a firm's choice of product architectures, as suggested by the Reverse Mirroring Hypothesis (RMH). In effect, the RMH implies that firms may face significant incentives to choose product architectures that mirror the organization architecture that each firm believes will help it to capture the greatest value in the form of gains from specialization and gains from trade—after taking into account the likely *ex ante* and *ex post* transactions costs associated with each choice of a given combination of product and organization architecture.

We now draw on our preceding analyses to summarize the nature of these incentives. The kind of product and organization architecture a firm chooses—a choice that we have represented as essentially between a stand-alone FSA and an ISA in which other firms can participate¹⁶—will have multiple strategic consequences. In the first instance, a firm's choice of an FSA or ISA will determine the extent to which a firm must provide its own components and supporting activities, one the one hand, or is able to access and use components and activities that may be provided by other firms and perhaps vice-versa, on the other.

If a firm believes that it has distinctive capabilities that would enable it to achieve the greatest benefit by capturing gains from specialization by bringing superior products to market, that would present an incentive for the firm to choose a stand-alone FSA. On the other hand, if a firm believes it can achieve greater benefit by capturing gains from trade by using components and activities sourced from other (specialist) firms, and perhaps by capturing gains from specialization by using its distinctive capabilities to provide other ISA firms with components and activities, there will be incentives for the firm to adopt an ISA—and very likely a modular ISA—in order to engage in cooperative exchanges and activities with other firms in the ISA regime. This mode of analysis suggests that even firms with

¹⁶ We note that both FSAs and ISAs as we have defined them here are essentially *ideal types*. That is to say, no FSA is likely to be completely *sui generis*, because it may share at least some basic 'industry standard' components that are used by other firms. Similarly, any firm's products leveraged from an ISA are likely to contain at least some components that are to some extent unique to a given firm. In practice, therefore, FSAs and ISAs will differ practically in the extent to which the 'core components' that provide the major functions and features in a given product type are unique to a firm's FSA or shared by other firms in an ISA.

moderate or no capabilities in component development and production may be able to participate profitably in an industry if they can capture gains from trade by sourcing components and activities from more capable firms participating in an ISA. These possibilities for capturing value from both specialization and trade stand in contrast to the traditional model of the atomistic, go-it-alone firm, whose strategy is to capture value through specialization by using its capabilities wholly within its own FSA.

By transacting for bilateral exchanges of components and activities within an ISA, firms may also benefit from several forms of reduced *ex ante* and *ex post* transaction costs (Williamson, 1985; Langlois, 2006; Baldwin, 2008). *Ex ante* transaction costs may be reduced by adopting an existing ISA or by sharing costs of defining and developing a new architecture and components among ISA participants. *Ex post* transaction costs may be reduced when standards for components and activities defined by an ISA lead to reduced costs for both unilateral and bilateral exchanges among participants in an ISA (Williamson 1985:21). In effect, while choosing an FSA may present a firm with an opportunity to incur relatively high *ex ante* transactions costs in order to enjoy relatively low *ex post* transactions costs, we have suggested that a strategic decision to use an ISA may offer firms a relatively low transaction-cost environment—*both ex ante and ex post*.

The joint decision process that we suggested in Figure 1 can now be elaborated as essentially a process of weighing the relative advantages of adopting an FSA versus an ISA. **Figure 4** summarizes the considerations a firm may recognize and address in its decision process for choosing an FSA or ISA. The decision process starts with a firm's evaluation of (i) the adequacy of its own capabilities to create a viable FSA, and (ii) whether creating an FSA offers the best prospect for capturing value from the firm's capabilities. These evaluations must then be compared with the firm's assessment of (i) the possibilities for joining an emergent or existing ISA or creating a new ISA, and (ii) the extent to which those possibilities offer attractive opportunities to capture value relative to creating an FSA. In both cases, we assume

that a firm's evaluations of its potential for capturing value consider both *ex ante* and *ex post* transactions costs attendant to each choice of architecture.

<<<<<< Insert **FIGURE 4** Here >>>>>>

Other considerations may of course have strategic importance in various contexts, but we suggest that the implications of a firm's architecture choices that we have summarized in Figure 4 form the core of the strategic concerns that must be addressed by a firm's managers in jointly deciding the product and organization architecture the firm will use.

HOW FIRM ARCHITECTURES MEDIATE PRODUCT MARKET AND INDUSTRY EVOLUTION

We now draw on our preceding discussion to summarize the role that the joint architecture decision process represented by the Mirroring Hypothesis and the Reverse Mirroring Hypothesis plays in our general model linking product market evolution, firms' architecture choices, and industry evolution.

As suggested in Figure 2, we propose that the collective architectural choices made by firms in an industry mediate between product market evolution (represented by firms' entrepreneurial responses to emerging market opportunities) and industry evolution (represented by changes in the architectures used in an industry and associated changes in competitive and cooperative inter-firm dynamics).

On the product market side, market opportunities arise from changes in customer preferences for various kinds of products. These changes may be driven by broad changes in the economy, society, values, and other macro-environmental factors (Kotler, 1994; Narver and Slater, 1990). Such changes in market preferences present firms with new opportunities to undertake entrepreneurial action to create new and improved products.

In this context it is important to note the implications for market evolution of Say's Law that 'supply creates its own demand' (Say, 1803). In effect, firms may not only react to changes in their environments, but may also seek to actively 'shape rapidly changing business environments' by creating new kinds of products and associated market processes (Teece, 2012: 1395; Pitelis and Teece, 2009). Thus, while much product market evolution is likely to invite incremental improvements within established product concepts and architectures (Worren, Moore, and Cardona, 2002), from time to time market evolution will create opportunities for firms to create new kinds of architectures for offering new kinds of products to the market (Kotler, 1997; Sanchez, 1995, 2008).

Thus, the architectures that firms choose may *both drive and be driven by* changes in markets. A market's evolving interest in new and improved products and firms' choices of architectures to serve those interests are therefore systemically interrelated and can be understood as co-evolving together.

On the industry side, we have suggested how firms' choices of architectures—which we have represented as most fundamentally a decision to use an FSA or an ISA—determine not just the kinds of architectures used in an industry, but also the ways in which and the extent to which firms will have opportunities to capture gains from specialization and/or gains from trade in the industry. The potential for firms to capture gains from specialization and trade that are enabled by their respective architectural choices in turn drive the dynamics of inter-firm interactions in an industry and largely determine the extent to which those dynamics will be competitive or cooperative. In effect, we have suggested that industry structures may also be understood as consisting of alternative *architecture-enabled systems* for capturing gains from specialization and trade.

Some of these architecture-enabled systems used in a given industry context may be closed-system FSAs through which individual firms compete, and some may be open-system ISAs in which potentially many firms both cooperate and compete. In choosing which kind of architecture-enabled system to use, firms may consider both the existing architectures already in use in its industry and the potential architectures that it may be possible to create individually or with other firms. In

making architectural choices, firms will weigh the potential gains from specialization and trade they believe they can capture by using a stand-alone FSA versus using an existing ISA or a potential ISA that could be created through cooperative interactions with other firms. Our general model suggests that the evolution of the architectures firms decide to use will be driven by their respective successes and failures in capturing gains from specialization and trade through use of alternative architecture-enabled systems for responding to evolving market opportunities.

CONCLUSION

We conclude by suggesting what we believe are some of the most important implications of the architectural perspective and analyses we develop here for both strategy theory and theories of economic organizing.

A more systemic representation of product and organization architectures

The Reverse Mirroring Hypothesis that we propose here addresses a relatively recent but important question in the ongoing discussion in the strategy literature about the relationships between product and organization architectures—i.e., the ways in which ‘organizations [decide to] design products’ (MacDuffie, 2013: 37–our amendment). Although substantial support has been found for Sanchez and Mahoney's (1996) originally posited influence of product architectures on firm's choices of organization architectures (the Mirroring Hypothesis), our Reverse Mirroring Hypothesis suggests that the causal relationship between product and organization architectures is likely to be bi-directional and thus systemic in nature. Our representation of product and organization architectures as systemically interdependent implies that firms are unlikely simply to let their choice of product architecture determine their organization architecture.

Rather, we suggest that firms' strategic organizing decisions will involve a joint architectural decision process in which each firm considers the strategic

implications of adopting alternative pairs of more or less aligned or 'mirroring' product and organization architectures. In this decision process, firms will consider the gains from trade they believe they can capture through use of closed-system, firm-specific product and organization architectures (FSAs) to compete against other firms. They will then compare those expected gains to the gains from specialization and trade they believe they can capture through use of open-system product and organization architectures (ISAs) that support both cooperative and competitive interactions with other firms.

We also suggest that this essentially comparative strategic evaluation and decision-making is an ongoing process driven by firms' evolving perceptions of the potential to capture gains by using alternative pairings of aligned product and organization architectures to respond to current and emerging market opportunities. Firms' evolving strategic organizing decisions to use FSAs or ISAs collectively drive the evolution of architectures and associated cooperative and competitive dynamics in an industry. This broader systemic perspective on firms' architectural choices leads us to propose our general model in which firms' architectural decisions mediate between the evolution of product markets and the evolution of industries and their competitive and cooperative dynamics.

A new perspective on industry structures

The architectural perspective we develop here supports some important elaborations beyond Porterian concepts of inter-firm interactions and industry structures (Porter 1980). In a basic sense, the technologies and resulting component designs and interface specifications that firms choose for their product architectures determine the *technical systems* that become the basis for their participation in an industry. When significant numbers of firms begin to use the component designs and interface specifications of an ISA to exchange components and to coordinate their activities, the interactions between firms no longer resemble the atomistic, zero-sum competition that is the staple of the classic Porterian view of

firm interactions. Rather, their interactions take on the character of the ‘coopetitive,’ positive-sum interactions of networks or ecosystems of firms that mutually benefit from using common technical and organizational structures (Sanchez 2008; Galvin and Morkel, 2001; Fixson and Park, 2008; MacDuffie, 2013).

In effect, the architectural perspective we suggest here enables us to see industries through a new lens that highlights *competing architecture-enabled systems for creating and capturing value*, some of which are supported by stand-alone firms using FSAs and some of which are supported by cooperating firms using common ISAs. We suggest that this perspective enables a useful, more contemporary interpretation of industry structures as being defined by the architectures that enable competing systems for value creation and capture in an industry, rather than being defined simply by the current market positions, customer bases, and product strategies of individual firms.

Integrating micro and macro views of economic organizing

We also suggest that our architectural perspective has significant potential to help achieve a useful integration of micro-economic and macro-economic theories of economic organizing (Sanchez and Mahoney, 2013). The architectural perspective we advance here not only identifies important interrelationships of intra-firm strategies, structures, and processes, but also suggests how decisions about those factors made at the firm level interact with and shape industry-level structures, processes, and competitive and cooperative dynamics. We suggest that the architectural perspective on firms and industries that we propose here may lead to better understanding of the systemic interrelationships between managerial decision-making about economic organizing at the firm level and the emergence of economic structures, processes, and dynamics at the industry level.

ISAs as a new dominant logic

Our discussion has also suggested that a firm that chooses to join or create an ISA may reduce both *ex ante* and *ex post* transaction costs and thereby improve its ability to capture value through transacting with firms participating in an ISA. If this

is so, then unless a firm has a clearly superior set of capabilities that enables it to capture greater gains through a stand-alone FSA, it appears that ISA regimes may offer a broadly advantageous way for firms to organize their economic activities. This expectation is consistent with a growing body of research suggesting that extensive ‘vertical disaggregation’ and use of collaborative development and outsourcing have become virtual norms in growing numbers of industries based on open-system, modular architectures (Sanchez, 2008; Cabigioso, Zirpoli, and Camuffo, 2012; MacDuffie, 2013; Kotha and Srikanth, 2013).¹⁷

Moreover, in a globalizing world in which capabilities of firms are rapidly rising—and in which any single firm is therefore less and less likely to have all the capabilities needed to develop and produce successful products on its own (McDermott, Mudambi, and Parente, 2013)—the ‘go-it-alone’ strategy inherent in adopting an FSA looks increasingly risky and unsustainable. As growing numbers of firms around the world acquire technological capabilities that enable them to develop and produce components and provide supporting services for many kinds of products, and as the processes and benefits of coopetition within ISAs become better understood, more firms may find it attractive to use modular ISAs rather than modular or non-modular FSAs (Sanchez and Collins, 2001). We suggest that the lower transaction costs and increased value-capture benefits enabled by open-system and modular architectures that we have identified here help to explain why use of modular ISAs may become a ‘dominant logic’ for competing in many kinds of product markets (Prahalad and Bettis, 1988; Sanchez, 1995, 2008; Argyres and Bigelow, 2010).

Suggestions for further research

¹⁷ Research also suggests some ‘demand-side’ reasons why ISAs are appearing more frequently in more industries, such as an aversion of buyers to being locked into firm-specific idiosyncratic architectures (Arthur, 1994), the potential for greater reliability and easier maintenance of ISA products compared to products based on idiosyncratic architectures (Sanchez, 2008), and the possibility of lower prices for products configured within an ISA compared to prices for products based on idiosyncratic FSAs (Garud and Kumaraswamy, 1995; Sanchez, 1999).

A key premise in our analysis of how a firm's choice of architectures may affect its potential gains from specialization and trade is the prospect that firms in an ISA will be able to sell their components and activities to other firms participating in the same ISA. By now the 'coopetition formula' of cooperating upstream in the development, production, and exchange of components while competing downstream in final product markets has become a familiar and readily observable phenomenon in many industries (Sanchez, 2008; Peng and Bourne, 2009; Peng *et al.*, 2012). Thus far, however, both economics and strategy have paid relatively little attention to the emergence and functioning of markets for exchanging intermediate inputs (i.e., components and services) in modular ISAs. Thus some shifting of focus in strategy and economics research from product market competition among individual firms to improving our understanding of how markets for cooperative exchanges of components and activities emerge within modular ISAs would now seem in order. Such research could no doubt help to lay the foundation for a more informed view of the strategic evaluations that managers must make in deciding the most advantageous kind of architectures on which to base the strategic organizing of their firms.

REFERENCES

- Abernathy W, Clark KB. 1985. Mapping the winds of creative destruction. *Research Policy* **14**(1): 3-22.
- Argyres NS, Bigelow L. 2010. Innovation, modularity and vertical de-integration: Evidence from the early U.S. auto industry. *Organization Science* **21**(3): 842-853.
- Argyres NS, Zenger T. 2012. Capabilities, transaction costs, and firm boundaries. *Organization Science* **23**(6): 1643-1657.
- Arrow KJ. 1974. *The Limits of Organization*. Norton: New York.
- Arthur WB. 1994. *Increasing Returns and Path Dependence in the Economy*, University of Michigan Press: Ann Arbor, MI.
- Baldwin CY. 2008. Where do transactions come from? Modularity, transactions, and the boundaries of firms. *Industrial and Corporate Change* **17**(1): 155-195.
- Baldwin CY, Clark KB. 1997. Managing in an age of modularity. *Harvard Business Review*, September-October: 84-93.
- Baldwin CY, Clark KB. 2000. *Design rules: Volume I. The Power of Modularity*. MIT Press: Cambridge MA.
- Boisot M, Sanchez R. 2010. Organization as a nexus of rules: Emergence in the evolution of systems and exchange. *Management Revue: The International Review of Management Studies* **21**(4): 378-405.
- Boudreau, K. (2010): Open platform strategies and innovation: Granting access vs. devolving control. *Management Science* **56**(10): 1849-1872.
- Brusoni S, Prencipe A, Pavitt K. 2001. Knowledge specialisation, organizational coupling and the boundaries of the firm: Why firms know more than they make? *Administrative Science Quarterly* **46**(4): 597-621.
- Cabigiosu A, Camuffo A. 2012. Beyond the 'mirroring' hypothesis: Product modularity and interorganizational relations in the air conditioning industry. *Organization Science* **23**(3): 686-703.
- Cabigiosu A, Zirpoli F, Camuffo A. 2013. Modularity, interfaces definition and the integration of external sources of innovation in the automotive industry. *Research Policy* **42**(3): 662-675.
- Campagnolo D, Camuffo A. 2010. The concept of modularity in management studies: A literature review. *International Journal of Management Reviews* **12**(3): 259-283.
- Carter R, Hodgson GM. 2006. The impact of empirical tests of transaction cost economics on the debate on the nature of the firm. *Strategic Management Journal* **27**(5): 461-476.
- Colfer LJ. 2007. The mirroring hypothesis: Theory and evidence on the correspondence between the structure of products and organizations. Harvard Business School, Cambridge/MA. Available at <http://www.people.hbs.edu/cbaldwin/DR2/ColferMirroring.pdf>, accessed on June 14, 2013.
- Colfer LJ, Baldwin CY. 2010. The mirroring hypothesis: Theory, evidence and exceptions. Working paper 10-58, Harvard Business School, Cambridge/MA. Available at <http://www.hbs.edu/faculty/Publication%20Files/10-058.pdf>, accessed on June 14, 2013.

- Fixson SK, Park J. 2008. The power of integrality: Linkages between product architecture, innovation, and industry structure. *Research Policy* **37**(8): 1296-1316.
- Fujimoto T. 2007. Architecture-based comparative advantage — a design information view of manufacturing. *Evolutionary and Institutional Economics Review* **4**(1): 55-112.
- Funk JL. 2008. Systems, components and modular design: the case of the US semiconductor industry. *International Journal of Technology Management* **42**(4): 387-413.
- Furlan A, Cabigiosu A, Camuffo A. 2013. When the mirror gets misted up: product modularity, inter-firm coordination, and component technological change. *Strategic Management Journal* DOI: 10.1002/smj.2138
- Galvin P. 1999. Product modularity, information structures and the diffusion of innovation. *International Journal of Technology Management* **17**(5): 467-479.
- Galvin P, Morkel A. 2001. The effect of product modularity on industry structure: The case of the world bicycle industry. *Industry & Innovation* **8**(1): 31-47.
- Garud R, Kumaraswamy A. 1995. Technological and organizational designs for realizing economies of substitution. *Strategic Management Journal* **16**(S1): 93-109.
- Gnyawali DR, He J, Madhavan R. 2006. Impact of co-opetition on firm competitive behavior: An empirical examination. *Journal of Management* **32**(4): 507-530.
- Hart O. 1995. *Firms, contracts, and financial structure*. Oxford University Press: New York.
- Hoetker G. 2006. Do modular products lead to modular organizations? *Strategic Management Journal* **27**(6): 501-518.
- Hunt SD, Morgan RM. 1995. The comparative advantage theory of competition. *Journal of Marketing* **59**: 1-15.
- Jacobides MG. 2005. Industry change through vertical dis-integration: How and why markets emerged in mortgage banking. *Academy of Management Journal* **48**(3): 465-498
- Jacobides MG, Billinger S. 2006. Designing the boundaries of the firm: From ‘make, buy, or ally’ to the dynamic benefits of vertical architecture. *Organization Science* **17**(2): 249-261.
- Jacobides MG, Knudsen T, Augier M. 2006. Benefiting from innovation: Value creation, value appropriation and the role of industry architectures. *Research Policy* **35**(8): 1200-1221.
- Klein B, Crawford RG, Alchian AA. Vertical integration, appropriable rents and competitive contracting process. *Journal of Law and Economics* **21**(2): 297-326.
- Kotha S, Srikanth K. 2013. Managing a global partnership model: lessons from the Boeing 787 ‘Dreamliner’ program. *Global Strategy Journal* **3**(1): 41-66.
- Kotler P. 1994. *Marketing Management: Analysis, Planning, Implementation, and Control* (8th edn). Prentice-Hall: Englewood Cliffs, NJ.
- Langlois RN. 2006. The secret life of mundane transaction costs. *Organization Studies* **27**(9): 1389-1410.
- Langlois RN, Garzarelli G. 2008. Of hackers and hairdressers: Modularity and the organizational economics of open-source collaboration. *Industry and Innovation* **15**(2): 125-143.

- MacDuffie JP. 2013. Modularity-as-property, modularization-as-process, and 'modularity'-as-frame: Lessons from product architecture initiatives in the global automotive industry. *Global Strategy Journal* **3**(1): 8–40.
- Macher JT, Richman BD. 2008. Transaction cost economics: an assessment of empirical research in the social sciences. *Business and Politics* **10**(1): 1–63.
- Madhok A. 2002. Reassessing the fundamentals and beyond: Ronald Coase, the transaction cost and resource-based theories of the firm and the institutional structure of production. *Strategic Management Journal* **23**: 535-550.
- McDermott G, Mudambi R, Parente R. 2013. Strategic modularity and the architecture of multinational firm. *Global Strategy Journal* **3**(1): 1-7.
- Nalebuff BJ, Brandenburger AM. 1996. *Co-opetition*. HarperCollins: London.
- Narver JC, Slater SF. 1990. The effect of a market orientation on business profitability. *Journal of Marketing* **54**(4): 20-35.
- Peng TJA, Bourne M. 2009. The coexistence of competition and cooperation between networks: implications from two Taiwanese healthcare networks. *British Journal of Management* **20**: 377-400.
- Peng TJA, Pike S, Yang JCH, Roos G. 2012. Is cooperation with competitors a good idea? An example in practice. *British Journal of Management* **23**: 532-560.
- Pitelis CN, Teece DJ. 2009. The (new) nature and essence of the firm. *European Management Review* **6**: 5–15.
- Porter ME. 1980: *Competitive Strategy: Techniques for Analyzing Industries and Competitors*. The Free Press: New York
- Prahalad CK, Bettis RA. 1988. The dominant logic: A new linkage between diversity and performance. *Strategic Management Journal* **7**(6): 485-501.
- Safizadeh MH, Field JM, Ritzman LP. 2008. Sourcing practices and boundaries of the firm in the financial services industry. *Strategic Management Journal* **29**(1): 79–91.
- Sah R., Stiglitz J. 1986. The architecture of economic systems: hierarchies and polyarchies. *American Economic Review* **76**(4): 716-727.
- Sako M. 2003. Modularity and outsourcing: The nature of co-evolution of product architecture and organization architecture in the global automotive industry. In: *The Business of Systems Integration* Prencipe A, Davies A, Hobday M. (eds). Oxford University Press: Oxford: 229-253.
- Sanchez R. 1995. Strategic flexibility in product competition. *Strategic Management Journal* **16**(S1): 135-159.
- Sanchez R. 1999. Modular architectures in the marketing process. *Journal of Marketing* **63**(Special Issue): 92-111.
- Sanchez R. 2000. Modular architectures, knowledge assets and organizational learning: new management processes for product creation. *International Journal of Technology Management* **19**(6): 610–629.
- Sanchez R. 2003. Integrating transactions costs theory and real options theory. *Managerial and Decision Economics* **24**(4): 267-282.

- Sanchez R. 2008. Modularity in the mediation of market and technology change. *International Journal of Technology Management* **42**(4): 331–364.
- Sanchez, R, Collins RP. 2001. Competing—and learning—in modular markets. *Long Range Planning* **34**(6): 645-667.
- Sanchez, R, Heene, A. 2004. *The New Strategic Management: Organization, Competition, and Competence*. John Wiley & Sons: New York and Chichester.
- Sanchez R, Mahoney J. 1996. Modularity, flexibility, and knowledge management in product and organization design. *Strategic Management Journal* **17**(Special Issue Winter): 63–76.
- Sanchez R, Mahoney J. 2013. Modularity and economic organization: Concepts, theory, observations, and predictions. In *Handbook of Economic Organization: Integrating Economic and Organization Theory*, Anna Grandori (ed). Edward Elgar: Los Angeles: 383-399.
- Sanderson SW, Uzumeri M. 1996. *Managing Product Families*. Irwin: Homewood, IL.
- Santos F, Abrunhosa A, Costa I. 2006. Strategic organization in mature industries: Boundary architecture as a source of competitive advantage. INSEAD working paper 2006/22/EFE. Paris, available at <http://www.insead.edu/facultyresearch/research/doc.cfm?did=1968>, accessed on June 14, 2013.
- Schilling MA. 2000. Toward a general modular systems theory and its application to inter-firm product modularity. *Academy of Management Review* **25**(2): 312-334.
- Schilling MA, Steensma HK. 2001. The use of modular organizational forms: An industry-level analysis. *Academy of Management Journal* **44**(6): 1149–1168.
- Shapiro, C., H. Varian. 1998. *Information Rules: A Strategic Guide to the Network Economy*. Harvard Business School Press: Boston/MA.
- Simon, H. A. (1969). Spurious correlation: A causal interpretation. *Journal of the American Statistical Association*, **49**(267):467-479.
- Simon, H. A. (1969). *The sciences of the artificial*. Cambridge, MA: The MIT Press.
- Smith, Adam. 1981. *An Inquiry into the Nature and Causes of the Wealth of Nations, Volumes I and II*. Liberty Fund: Indianapolis. (Originally published in 1776.)
- Spender JC. 1989: *Industry recipes. An inquiry into the nature and sources of managerial judgment*. Basil Blackwell: Cambridge/MA.
- Stigler GJ, Sherwin RA. 1985. The extent of a market. *Journal of Law and Economics* **28**: 555–585.
- Teece DJ. 1986. Profiting from technological innovation: Implications for integration collaboration, licensing and public policy. *Research Policy* **15**(6) 285-305.
- Teece DJ. 2012. Dynamic capabilities: Routines versus entrepreneurial action. *Journal of Management Studies* **49**(8): 1395-1401.
- West J. 2003. How open is open enough? Melding proprietary and open source platform strategies. *Research Policy* **32**(7) 1259–1285.
- Williamson OE. 1979. Transaction cost economics: The governance of contractual relations. *Journal of Law and Economics* **22**: 233-261.
- Williamson OE. 1985: *The economic institutions of capitalism*. The Free Press: New York

- Worren N, Moore K, Cardona P. 2002. Modularity, strategic flexibility, and firm performance: a study of the home appliance industry. *Strategic Management Journal* **23**(12): 1123–1140.
- Zajac, E.J., Olson, C.P. 1993: From transaction cost to transactional value analysis: Implications for the study of inter-organizational strategies. In: *Journal of Management Studies* **30**(1993): 131–145.

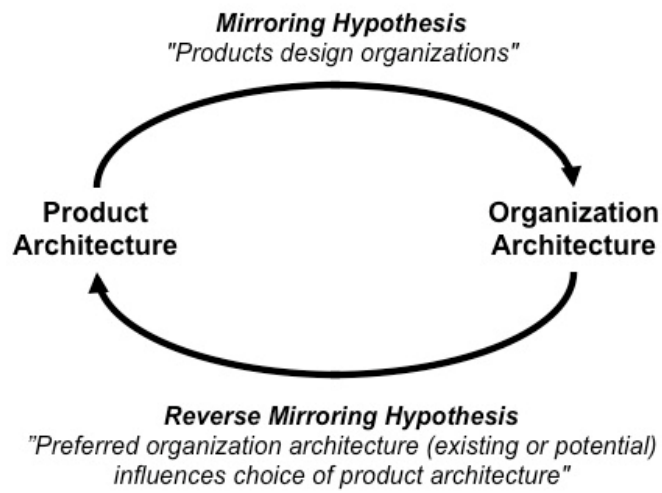


Figure 1: Systemic interrelationships of product and organization architectures imply *both* mirroring hypothesis and reverse mirroring hypothesis

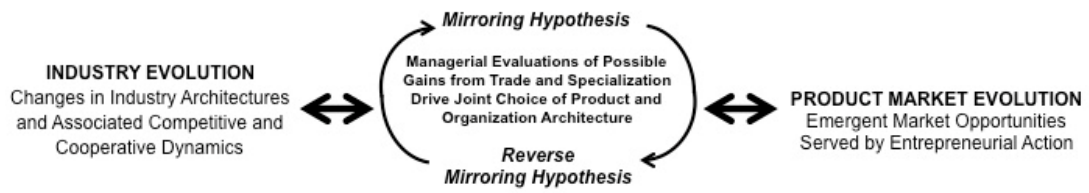


Figure 2: Systemic interrelationships of product market evolution, firm choices of product and organization architectures, and industry evolution

		System properties of architecture	
		Open system	Closed system
Modularity properties of architecture	Substantially modular	<p>Open-system Modular architecture (Modular ISA) Architecture with high levels of commonality support cooperative activities and exchange of components to provide participating firms with product variations and upgrades, and lower costs</p>	<p>Closed system Modular architecture (Modular FSA) A proprietary architecture with high levels of specificity within which a controlling firm's internal capabilities and licensed subcontracting are relied on to provide product variations</p>
	Non-modular	<p>Open-system Non-modular architecture (Non-modular ISA) Architecture with high level of commonality enabling participating firms to act as autonomous component producers and/or product assemblers In offering a limited range of product variations</p>	<p>Closed-system Non-modular architecture (Non-modular FSA) A proprietary architecture with high levels of specificity within which a firm's internal capabilities and licensed subcontracting provide a limited range of product variations and infrequent upgrades</p>

Figure 3: Types of architectures and their associated inter-firm dynamics

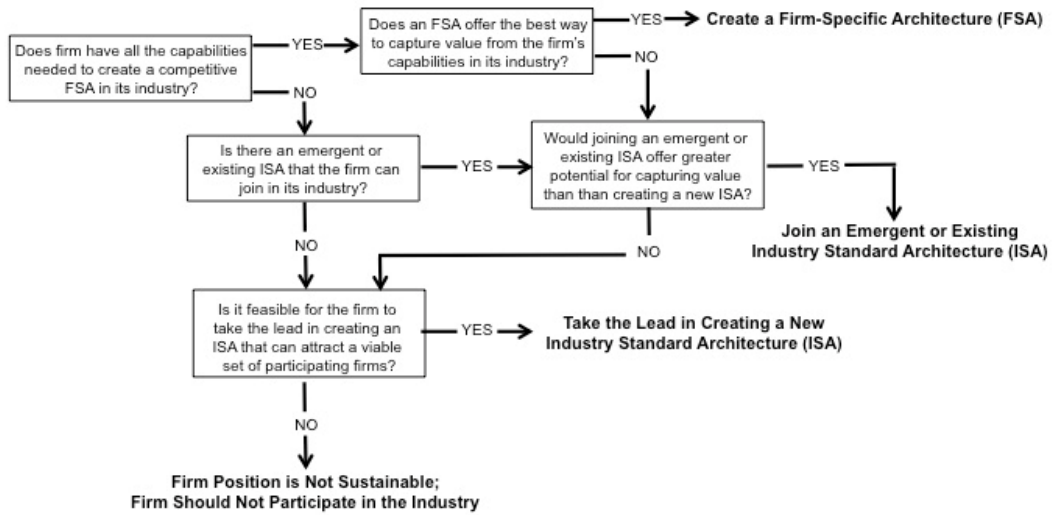


Figure 4: Process for deciding architecture strategy in an industry