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## RESEARCH ARTICLE

# A third dimension in the mirror? How senior managers design products and organizations

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## Abstract

Individual CEO characteristics may affect architectural choices through the application of managerial discretion. Systems such as organizations and their products are not purely driven toward modularity because of external forces. Individual CEO characteristics may constitute an additional dimension to established mirroring considerations that impacts both the choice of architecture and the correspondence between product and organization architectures.

## 1 | INTRODUCTION

How different pairings of firms' product architecture and organization architecture arise and evolve over time, and whether there is a mirroring across these different architectural levels is subject to a number of factors both external and internal to the firm (e.g., Colfer, 2007; Colfer & Baldwin, 2016; Sorkun & Furlan, 2017). While originally proposed in the form "products design organizations" (Sanchez & Mahoney, 1996), the direction of this so-called mirroring hypothesis has been questioned. Complementing the original reasoning, Sanchez, Galvin, and Bach (2013) suggest a "reverse mirroring hypothesis" to also allow for "organizations designing products."

Configuring complex systems such as product and organization architectures and the respective supply chain is a design task (Baldwin & Clark, 2000; Jacobides, 2005; Puranam, Alexy, & Reitzig, 2014). The design challenge is to create a technical architecture and corresponding organization architecture that together are capable of carrying out complex tasks in efficient ways that allow the firm to compete in dynamic environments. Originating from the literature on strategic flexibility (Brozovic, 2018; Harrigan, 1985; Sanchez, 1995; Sanchez & Mahoney, 1996; Warren, Moore, & Cardona, 2002) scholars put forward the notion that "strategizing managers" seek the best combination of modular and integrated architecture pairings to allow the firm to capture value from both gains from specialization and gains from trade (Sanchez, Galvin, & Bach, 2013; Sanchez &

Mahoney, 2013). A key question is whether such architectural choices are the result of the "iron cage" of institutional forces and isomorphic pressures (DiMaggio & Powell, 1983) or whether it is the individual characteristics of top manager's that drive these architectural choices. While the degree of managerial discretion may vary between industries, we build our arguments using an upper echelons perspective (e.g., Hambrick & Mason, 1984). Our analysis is rooted in the assumption that managerial choices are not purely the result of external forces and that managers and their individual characteristics do matter.

The extant literature shows empirical support for such a "CEO-effect" on firm performance (Liu, Fisher, & Chen, 2018; Quigley, Crossland, & Campbell, 2017; Quigley & Hambrick, 2015). Individual characteristics such as the CEO's age, tenure, experience, and personality affect firms' strategic choices and firm performance (for a meta-analysis, see Wang, Holmes Jr., Oh, & Zhu, 2016). Following this rationale, we argue that top managers' individual characteristics influence firms' architectural choices. To build our theoretical position, we first summarize the literature on architectural choice and the mirroring hypothesis. We then present the core findings of the CEO effect as a conceptual foundation of our analysis. Combining architectural choice (dependent variable) and CEO effect (independent variable) we then derive propositions how individual CEO characteristics affect firms' architectural choices. The paper ends with a discussion relating our propositions to the literature on mirroring and misting and the embeddedness of firm architectures in industry architectures.

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## 2 | MODULARITY, STRATEGIC FLEXIBILITY, AND ARCHITECTURAL CHOICES

At its heart, modularity theory considers a system's ability to separate and recombine its elements without much loss of its functionality on the basis of assigning functionalities to modules, defining interfaces between the modules, and enacting standards that allow an assessment of the performance of a module (Baldwin & Clark, 2000; Campagnolo & Camuffo, 2010; Schilling, 2000). Applying the concept of modularity to organizations, Sanchez and Mahoney (1996) contend that the natural boundary of a firm is determined by its production technology. This mirroring hypothesis (Baldwin, 2008; Colfer, 2007; Colfer & Baldwin, 2016) specifically links an organization's task structure to the actions of making and selling the outcomes of individual tasks. Hence, as products and production technologies change, so do a firm's task structure and boundaries. While the most common view is that "products design organizations" (Sanchez & Mahoney, 1996), there is also empirical evidence for product design following organization design (Fine & Whitney, 1996; Fixson & Park, 2008). Hence, the direction of causality can be of either direction (Campagnolo & Camuffo, 2009; MacDuffie, 2013). Research to date has moved from questioning whether mirroring occurs to conditions under which the mirroring holds, and when hybrid architecture pairings—simultaneous mirroring and misting—arise (Burton & Galvin, 2018). However, this research has focused very much on product characteristics (e.g., product complexity and rate of component change). We posit that the drivers of architectural choices are likely to go further and as such we introduce how managerial discretion and individual managers may affect firms' architectural choices, and subsequent mirroring and misting.

Why do managers choose modular or integrated architectures? The key rationale to choose modular architectures is that they allow firms to react quicker and more easily to competitive forces; product modularity is an enabler of firms' strategic flexibility (Sanchez, 1995; Schilling & Vasco, 2000; Worren et al., 2002). A modular product design also allows the firm to organize its product development in a modular structure, assigning certain development tasks to specialized actors (Cabigiosu & Camuffo, 2012; Hoetker, 2006). In addition to using specialized knowledge for each component, a modular architecture has benefits at the architectural level: A modular architecture allows "each functional element of the product to be changed independently by changing only the corresponding component [whereas] ... fully integral products require changes to every component to effect change in any single functional element" (Ulrich, 1995, p. 426). As a result of these technical system characteristics firms can (a) more easily redefine their product strategies, (b) redeploy their chains of resources in support of these refined product strategies, and (c) redefine their product offering by including new resources in their product creation processes (Sanchez, 1995).

While strategic flexibility seems favorable in dynamic environments, there is also a downside to choosing modular architectures. Studies on industries in which modular architectures are prevalent

have shown that a shift toward modularity does not come without a price. First of all, while a modular task structure enables transactions, modularization is costly (Baldwin, 2008; MacDuffie, 2013). Standardizing components and interfaces evokes high ex-ante transaction costs that only pay off if subsequent transactions are high in number. Second, the more specialized knowledge in modular architectures blurs the perception on the "big picture"; modular architectures are known to lead to a "modularity trap" (Chesbrough & Kusunoki, 2001; Henderson & Clark, 1990). In modular architectures, learning takes place mainly at the component level (Sanchez & Mahoney, 1996). Technological shifts at the architectural level are unlikely because they are not in the interest of both neither component manufacturers nor the owners of previously sold products (Chesbrough & Kusunoki, 2001; Galvin, 1999; Henderson & Clark, 1990).

When referring to "architectures" or "architectural choices" we subsequently take the (reverse) mirroring hypotheses for granted and refer to mirrored pairings of product and organization architectures. Whenever we discuss a hybrid pairing or refer to only one of the architectures we will explicitly use the terms "product architecture" and/or "organization architecture".

Fundamentally, choosing a product and organization architecture means choosing which markets to target and which value to capture (MacDuffie, 2013). The different types of value associated with integrated versus modular architectures have been elaborated in detail (e.g., Sanchez, 2002, 2008). The general notion is that a given performance or cost optimization goal for a production system can be achieved more effectively using an integrated architecture. Vice versa, modular architectures allow quicker reaction to market changes and through the plug-and-play capability, the same architecture allows more product variety. Furthermore, modularization enables transactions (Baldwin, 2008) with other, specialized actors, which in turn allows to benefit from external economies of scale in intermediate markets (Jacobides, 2005), and to tap into collective knowledge and learning processes (Langlois & Garzarelli, 2008). Summarizing all these effects in an architectural decision making process, Sanchez, Galvin, and Bach (2013) argue that a firm's joint choice of product and organization architectures will be driven in important part by its assessments of value capture through gains from specialization and gains from trade (Jacobides, 2005; Jacobides & Billinger, 2006; Sanchez, 2008, 2012). A product—for example, a car—may be modular in some functions (e.g., the wheels) and integrated in others (e.g., integrated body). Because rims and tires are not custom built, car manufacturers can achieve both gains from specialization and gains from trade by choosing a modular design for the wheels with market standard interfaces. On the other hand, given performance and/or cost targets in the production system can be more easily achieved with an integrated design for example, for the car body. As a result of these assessments, firms choose such combinations of integrated and modular components for which they expect the highest value generation.

Managers also have to choose whether the product and organization architecture should mirror each other (mirroring) or differ in total (misted mirror) or in part (partial mirroring and partial misting); this has been found for example in a study of the laptop computer

industry (Hoetker, 2006). The factors that lead to “mist in the mirror” have been identified as high levels of product complexity (e.g., MacDuffie, 2013; Zirpoli & Becker, 2011) and a high rate of component change (Furlan, Cabigiosu, & Camuffo, 2014). Also, a number of contextual product characteristics leads to “simultaneous mirroring and misting,” “partial mirroring,” or “hybrid pairings” (Burton & Galvin, 2018).

Summarizing the above literature review on architecture choice firms seek to create value by choosing combinations of modular or integrated designs depending on (a) given performance or cost targets and (b) the availability of specialized knowledge and the cost to connect with (intermediate) markets through which this knowledge can be accessed.

### 3 | UPPER ECHELONS THEORY AND CEO EFFECT

At its core upper echelons theory (UET) argues that firms' strategic choices are not purely determined by external factors and that managers do matter. In this article we posit that—as any other strategic decision—architectural choices also depend on managers and their individual characteristics. The rationale of UET states that executives act on the basis of their personal interpretation of the strategic situation as a function of their experience, values, and personality (Hambrick, 2007; Hambrick & Mason, 1984). Based on the seminal article by Hambrick and Mason (1984), three UET streams of research coevolved (Liu et al., 2018). The probably largest and most influential UET research stream examines which attributes of top management as a team (e.g., team composition) affect firm performance (e.g., Finkelstein & Hambrick, 1990; Kilduff, Angelmar, & Mehra, 2000). A second stream—which we focus on—comprises studies of how individual CEO attributes are related to firm strategy (e.g., Chatterjee & Hambrick, 2007, 2011; Hayward & Hambrick, 1997; Simsek, Heavey, & Veiga, 2010). The results of this research stream are also known as the CEO effect (e.g., Quigley & Hambrick, 2015). Finally, the third research stream considers how individual CEO attributes impact top management team (TMT) processes (e.g., Ling, Simsek, Lubatkin, & Veiga, 2008; Ou et al., 2014; Simsek, 2007).

To derive propositions for architectural choices we focus upon the CEO effect literature stream. Originating from Hambrick and Mason's (1984) original model, empirical research has investigated a variety of performance effects such as diversification, innovation, and strategic change. Individual attributes as independent variables in the empirical studies include the CEO's age (Hitt & Tyler, 1991; Yim, 2013), gender (Chen, Crossland, & Huang, 2016; DeJoy, 1992; Eckel & Grossman, 2008), functional experience (Barker & Mueller, 2002; Datta & Rajagopalan, 1998), education (Ng & Feldman, 2009), international experience (Carpenter, Sanders, & Gregersen, 2001; Khavul, Benson, & Datta, 2010), and a number of personality attributes (Chatterjee & Hambrick, 2011; Chen, Crossland, & Luo, 2015; Hiller & Hambrick, 2005; Simsek et al., 2010).

The subsequent sections summarize the arguments on CEO age, tenure, formal education, prior experience, and personality identified as key variables in a meta-analysis by Wang et al. (2016).

#### 3.1 | CEO age

Hambrick and Mason (1984) argued that firms led by younger CEOs take more risk. Younger CEOs have accumulated less personal wealth than older CEOs; they have less to lose. Hence, young CEOs will be more likely to initiate aggressive strategic actions to generate personal and organizational wealth than older CEOs (Yim, 2013). On the other hand, older CEOs possess more complex cognitive schemes, accumulated and refined during their lifetime. While this provides a larger knowledge base to assess and interpret new information correctly, it takes older CEOs more time to learn and to integrate new information. Furthermore, older CEOs may have a stronger interest in protecting their accumulated wealth. As a result, older CEOs might be more committed to the status quo and less likely to take risk (Serfling, 2014). Empirically, the meta-analysis by Wang et al. (2016) finds that CEO age is significantly and negatively related to firm risk taking and product innovation.

#### 3.2 | CEO tenure

CEO tenure is among the most studied CEO characteristics in UET research (Finkelstein, Hambrick, & Cannella Jr., 2009). Because short-tenured CEOs have less experience in the CEO position, they are more likely to experiment with different strategies (Hambrick & Fukutomi, 1991). Later on, as their career advances, CEOs build legacy. The longer their tenure, the less CEOs are willing to put their legacies at risk (Matta & Beamish, 2008). Also, early in their tenure CEOs are at higher risk of dismissal (Shen & Cannella Jr., 2002); this motivates them to take higher risks and prove their competence (e.g., Prendergast & Stole, 1996). Empirically, the meta-analysis by Wang et al. (2016) finds that CEO tenure is significantly and negatively related to strategic risk and strategic change. Furthermore CEO tenure has a significant and negative relationship with product diversification.

#### 3.3 | CEO formal education

CEO formal education is a proxy of CEO cognitive ability, empirically studied as the amount of formal schooling received or the number of postsecondary degrees CEOs hold. The higher the cognitive ability, the easier CEOs acquire and process complex information and the faster they make decisions (Wally & Baum, 1994). Formal education also may indicate a CEO's openness to novel concepts (Thomas, Litschert, & Ramaswamy, 1991). Similarly, formal education results in rich knowledge bases and skill sets that allow CEOs to understand and process information more quickly and accurately (Kimberly &

Evanisko, 1981; Ng & Feldman, 2009). Empirically, the meta-analysis by Wang et al. (2016) shows a positive and significant correlation between CEO formal education and strategic scope, strategic risk, and strategic change.

### 3.4 | CEO experience

Prior CEO career experiences shape CEOs cognitive schemes, how they perceive and process information, and how they utilize it to make decisions (Dearborn & Simon, 1958; Hambrick & Mason, 1984; Lawrence & Lorsch, 1967). In particular, the CEO's functional background (e.g., throughput experience like production) to a high degree determines which business strategies are pursued and which projects are given higher priority. Because of their functional perspective and functional targets, marketing and sales managers set other priorities than operations or procurement managers. Other aspects of CEO experience studied in UET research include international experience (e.g., Khavul et al., 2010), industry experience (Simsek, 2007), and prior career experience in executive-level positions at other firms before becoming the CEO (e.g., Zhang, 2008). In general, with experience CEOs become more comfortable to make decisions and to implement them (Liu et al., 2018). While the effect of CEO experience is theoretically sound, due to aggregate measures of experience, the meta-analysis by Wang et al. (2016) finds no significant support for general measures of experience. However, an analysis of more specific experience categories shows a significant and positive relationship between CEO task experience and strategic scope and strategic risk.

### 3.5 | CEO personality

UET research on CEO personality typically examines constructs related to positive self-concept. Individuals with positive self-concept hold favorable self-images and are more likely to view themselves as exceptional, potent, admirable, and important (Finkelstein et al., 2009; Hiller & Hambrick, 2005; Judge, Locke, & Durham, 1997). As positive self-concept increases, CEOs are more confident in themselves and their capabilities, are less focused on their own limitations, experience less anxiety, and are more comfortable making decisions to pursue "large-stakes initiatives" (Hiller & Hambrick, 2005, p. 311). Empirically, the meta-analysis by Wang et al. (2016) shows that CEO positive self-concept is positively associated with the category of strategic risk.

## 4 | ANALYSIS AND PROPOSITIONS

Modularity has been described as a cognitive frame (MacDuffie, 2013). Only if managers understand the advantages of product modularity and develop the managerial skills to manage modular organizations they will be able to choose and implement modular strategies (Baldwin & Clark, 2000; Sanchez, 1995). Sanchez and Mahoney

(2013: 389) explicitly address such "managerial and organizational factors" as enablers and limitations to pursuing a modular strategy. In their decision process, managers must first realize the speed and flexibility advantages of modular designs, and second they also must be willing and able to undertake the strategic organizational change required to implement modular designs.

In a similar vein, MacDuffie (2013) explicitly differentiates "modularity as frame" as a prerequisite to modularization processes and modular designs. Based on his analysis of the global automotive industry, he argues that modularity-as-frame drives the directionality of the interplay between modularity-as-property and modularization-as-process. Fundamentally, the concept of modularity is argued to be "a powerful cognitive frame" (MacDuffie, 2013, p. 37) for managers taking design choices, reflecting the goals of the senior leader or dominant coalition.

We take the notion of modularity-as-frame as our baseline argument: managers cognitive frames are a prerequisite for modular designs, and managers (modular) cognitive frames constitute a third dimension in the mirroring hypothesis. This leads to our first and second proposition regarding the CEO effect on architectural design choice:

**Proposition 1a** *Managers will choose modular designs (mirrored or misted pairings of modular product and modular organization design) only if they possess a cognitive frame of modularity that (a) is applicable to their firm, and (b) leads to positive evaluations.*

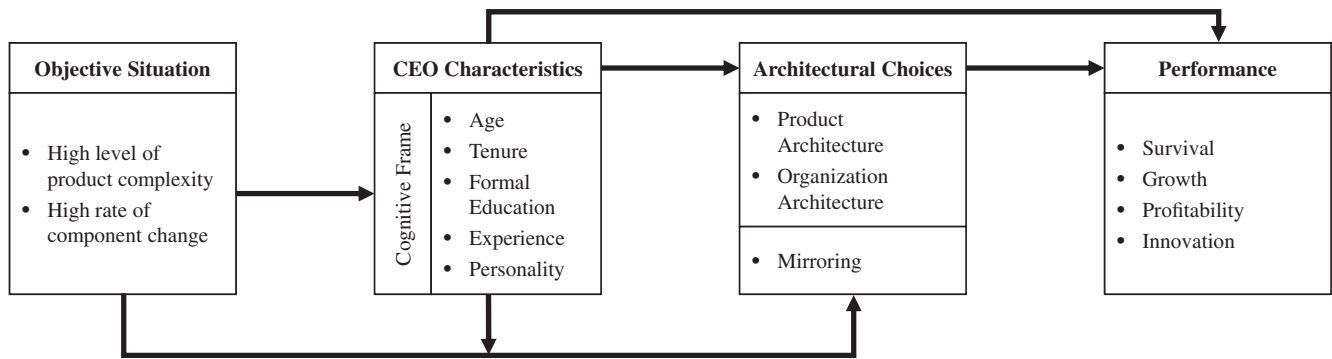
**Proposition 1b** *Managers will choose misted or hybrid pairings of product and organization design only if their cognitive frame of modularity (a) allows deviations from the mirroring and (b) these deviations are expected to bear lower risks or to yield better results.*

Applying these baseline hypotheses to the UET model of strategic choice leads to a model as shown in Figure 1. In addition to the original UET model, we posit that individual CEO characteristics will have a moderating effect on the degree to which the level of product complexity and the rate of component change CEOs affect the isomorphism between and mirroring of product and organization architecture.

We now turn to individual CEO characteristics that are known to affect CEO's strategic choices and for each of these characteristics we derive propositions for both the direct effect on architectural choice and the moderating effect on (partial) mirroring.

### 4.1 | CEO age

Older CEOs possess more complex cognitive schemes, as may be necessary to grasp integrated architectures. Hence, younger CEOs may not be capable to understand the interconnection of integrated architectures. Furthermore, modular architectures allow firms to respond to changes in demand more quickly. Taking advantage of



**FIGURE 1** Upper echelons theory, CEO effect, and architectural choices

the plug-and-play functionality of modular architectures requires quick but less refined learning processes; this is easier for younger CEOs. Older managers learn slower, but relate new knowledge to their broad and refined cognitive schemes. Such learning processes are better suited to enhance an established architecture. On the contrary, making investments in new components or taking new suppliers on board in a modular architecture requires a learning style which is more often found among younger CEOs. Hence, we posit:

**Proposition 2a** *Older CEOs are more likely to choose integrated architectures whereas younger CEOs will prefer modular architectures.*

We also expect CEO age to affect the effects of both product complexity and rate of component change on the mirroring hypothesis. High levels of product complexity and a high rate of component change lead to “mist in the mirror.” Both require quick learning processes, which is easier for younger CEOs. We posit:

**Proposition 2b** *The effect of product complexity and rate of component change on the mirroring hypothesis (misted mirror) will be stronger for younger CEOs than for older CEOs.*

## 4.2 | CEO tenure

Short-tenured CEOs are more likely to experiment with different strategies before they build a legacy. Such managerial action is easier within modular architectures providing a plug-and-play functionality of the components. Empirically CEO tenure is significantly and negatively related to strategic change and product diversification. This leads to the assumption that once a strategy proves successful, CEOs hold on to that strategy with continuing tenure. Consistent strategy over time does not require strategic flexibility anymore and, therefore, longer tenured CEOs may focus performance targets within cost constraints. From an architectural perspective, such strategic goals are easier to achieve choosing integrated architectures. Hence, longer tenured CEOs are more likely to favor integrated architectures.

**Proposition 3a** *CEOs with longer tenure are more likely to choose integrated architectures whereas CEOs with shorter tenure will prefer modular architectures.*

With CEO age, we expect CEO tenure to moderate the effect of product complexity and rate of component change on the mirroring hypothesis. High levels of product complexity and a high rate of component change can only be mastered with a flexible strategy. This is more likely for shorter tenured CEOs. We posit:

**Proposition 3b** *The effect of product complexity and rate of component change on the mirroring hypothesis (mist in the mirror) will be stronger for CEOs with shorter tenure than for CEOs with longer tenure.*

## 4.3 | CEO formal education

The higher the cognitive ability, the easier CEOs acquire and process information, and the faster they make decisions (Wally & Baum, 1994). Empirically, the meta-analysis by Wang et al. (2016) shows a positive and significant correlation between CEO formal education and strategic scope, strategic risk, and strategic change. Modular architectures allow changes in scope and strategic change by changing individual components based on market demands. To monitor a number of (potential) markets and to process the respective information requires higher cognitive abilities than monitoring changes in demand within the scope of an integrated architecture. Hence we posit:

**Proposition 4a** *CEOs with a higher degree of formal education are more likely to choose modular architectures whereas CEOs with low formal education are more likely to choose integrated architectures.*

CEO formal education and their cognitive abilities also moderate the effect of product complexity and rate of component change on the mirroring hypothesis. High levels of product complexity and a high rate of component change are easier to master with higher cognitive abilities. We posit:

**Proposition 4b** *The effect of product complexity and rate of component change on the mirroring hypothesis will be stronger for CEOs with more formal education than for CEOs with less formal education.*

#### 4.4 | CEO experience

CEO prior career experiences shape CEOs cognitive schemes, how they perceive and process information, which priorities they assign, and how they make decisions (Dearborn & Simon, 1958; Hambrick & Mason, 1984; Lawrence & Lorsch, 1967). We argue that CEOs with a functional background in output functions (e.g., sales, marketing) give higher priority to market requirements and changes in customer preferences. This is easier to achieve using modular architectures. On the contrary, CEOs with a functional background in throughput functions (e.g., operations, logistics) will give higher priority to given performance goals under cost restrictions. This is easier to achieve choosing integrated architectures. We posit:

**Proposition 5a** *CEOs with a functional background and task experience in throughput functions are more likely to choose integrated architectures whereas CEOs with a functional background and task experience in an output function will prefer modular architectures.*

CEOs functional background and task experience also moderate the effect of product complexity and rate of component change on the mirroring hypothesis. High levels of product complexity and a high rate of component change, because of their task experience, are more easily recognized and then given higher priority by CEOs with task experience in an output-oriented function. Vice versa, CEOs with task experience in a throughput-oriented function will not as easily process information on high product complexity and high rate of component change. We posit:

**Proposition 5b** *The effect of product complexity and rate of component change on the mirroring hypothesis (misted mirror) will be stronger for CEOs with task experience in output-oriented functions and will be smaller for CEOs with task experience in throughput-oriented functions.*

#### 4.5 | CEO personality

As positive self-concept increases, CEOs are more confident in themselves and their capabilities, are less focused on their own limitations, experience less anxiety, and are more comfortable making decisions to pursue "large-stakes initiatives" (Hiller & Hambrick, 2005, p. 311). Empirically, the meta-analysis by Wang et al. (2016) shows that CEO positive self-concept is positively associated with the category of strategic risk. Based on these findings we argue that managing integrated architectures requires a more positive self-concept than managing a modular architecture. Because of their plug and play functionality, modular designs allow to spread risk. While each market interface in a

modular architecture involves dealing with market uncertainty and behavioral risks of cheating suppliers, each supplier may be replaced by another supplier. On the contrary, from a risk-taking perspective, choosing an integrated architecture means putting all eggs in one basket. We posit:

**Proposition 6a** *CEOs with a less positive self-concept are more likely to choose modular architectures whereas CEOs with a high positive self-concept will prefer integrated architectures.*

As strategic risk correlates with positive self-concept, we argue that positive self-concept moderates the effect of product complexity and rate of component change on the mirroring hypothesis. High levels of product complexity and a high rate of component change invoke higher strategic risks than low complexity and a low rate of change. We posit:

**Proposition 6b** *The effect of product complexity and rate of component change on the mirroring hypothesis (misted mirror) will be stronger for CEOs with a high positive self-concept than for CEOs with a less positive self-concept.*

A summary of the above analysis and the main rationale for each of the CEO characteristics is depicted in Figure 2.

## 5 | DISCUSSION

In this article we argue that the CEO effect known from UET research also applies to architectural choices and the mirroring hypothesis. Fundamentally, we argue that individual CEO characteristics and the respective cognitive frames constitute a third dimension in the mirror. Managers only choose modular architectures if they possess a cognitive frame that allows for decomposing the system in modules with defined functions. The process of modularization will only be started if managers can grasp the advantages of modular architectures and if they believe in higher value capture for modular designs in the markets they serve.

Our analysis of individual CEO characteristics shows that there are causal relations between CEO characteristics and architectural choice. Furthermore, individual CEO characteristics also have a moderating effect on the effect of product complexity and rate of component change on the type of mirroring. The theoretically derived causal effects of age dependent learning styles, tenure influencing strategic flexibility, cognitive abilities limiting or enabling strategic scope, task experience affecting priorities, and CEO personality as a determinant of risk taking, all support the notion of a CEO effect on architectural choice and mirroring.

With our analysis we contribute to both UET and modularity theory. Regarding UET, we expand the range of strategic choices analyzed by adding architectural choices as a dependent variable. With our propositions, we show that the general UET model also can be applied to managers' architectural choices. Furthermore, we show that

Individual CEO Characteristic	Rationale	Choice: Modular Architectures	Choice: Integrated Architectures	Moderating Effect on Mirroring Hypothesis
Age	Learning style	Younger CEOs learn faster which is needed to take advantage of plug & play functionality	Older CEOs possess more refined knowledge which is needed to grasp integrated designs	The effect of misting determinants will be stronger for younger CEOs
Tenure	Flexibility vs. legacy	Less tenured CEOs are more inclined to strategic change and diversification	Longer tenured CEOs hold on to their legacy	The effect of misting determinants will be stronger for CEOs with shorter tenure
Formal education	Cognitive ability	More market interfaces (and respective changes in demand) require higher cognitive abilities	Fewer market interfaces (and respective changes in demand) require lower cognitive abilities	The effect of misting determinants will be stronger for CEOs with higher formal education
Task experience	Focus of priorities	CEOs with task experience in market related functions give higher priority to strategic flexibility	CEOs with task experience in throughput functions give higher priority to given performance and cost targets	The effect of misting determinants will be stronger for CEOs with task experience in output-oriented functions
Personality	Positive self-concept and risk taking	Modular designs allow plug & play changes in components which implies risk spreading	Integrated designs imply risk bundling	The effect of misting determinants will be stronger for CEOs with higher positive self-concept

**FIGURE 2** Propositions regarding CEO effect and architectural choices

individual CEO characteristics moderate direct effects from the environment on strategic choice. Regarding modularity theory, other than in Schilling's (2000) seminal article, we highlight that it is not systems "being driven" or "evolving" or "adapting to changes." It is managers that make architectural choices based on their perception of the external environment and their information processing based on their individual characteristics. We propose a CEO effect in systems being modular or integrated.

Our analysis at the moment is pure theoretical reasoning. In a next step, the propositions will need to be refined and be formulated as hypotheses that can be put to an empirical test. Future research should also include findings from the other two streams in UET research, namely top management teams and the effect of individual CEO characteristics on top management team processes.

Expanding the findings from this article on architectural choices at the firm level to architectures at the industry level, future research should address the question how individual CEO characteristics shape the evolution of industry standard architectures (Jacobides, Knudsen, & Augier, 2006; Sanchez, Galvin, & Bach, 2013). While institutional theory may explain this phenomenon through institutional forces and mimetic processes at the firm level, this finding may have a micro-foundation in CEOs with similar cognitive frames based on similar CEO characteristics. From a UET perspective it would not be surprising that CEOs of similar age and tenure, having served in the same industry in similar functions, in a given industry environment take the same architectural choices.

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