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Focus in Searching Core–Periphery Structures

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Abstract. Organizations are often conceptualized as systems of interdependent choices that exhibit a core–periphery structure. Research is inconclusive, however, regarding whether organizations should focus their search efforts on their core or peripheral choices. In this paper, we seek to reconcile contradictory arguments and suggest that the efficacy of a search focus depends on the time horizon, environmental change, and how the core and periphery interact. In so doing, we demonstrate that the directionality of interdependence and whether interdependencies occur mostly within the core or between the core and periphery are key determinants of the implications of focus. We discuss the implications of our findings for various streams of research, including research on structural inertia and business model innovation.

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Introduction

Organizations are often conceptualized as systems of interdependent choices, particularly in the literature on organizational adaptation (Levinthal 1997), activity systems (Porter and Siggelkow 2008), business models (Zott and Amit 2010), manufacturing systems (Milgrom and Roberts 1990), organizational strategy (Siggelkow 2011), and structural inertia (Hannan and Freeman 1984). In this view, organizational performance is determined by the interplay of a set of interconnected choices rather than by (the sum of) individual choices. In conceptualizing organizations as a set of interdependent choices, research has also often argued that some choices are more connected than others (e.g., Hannan et al. 1996, Siggelkow 2002). These more connected choices are commonly referred to as core choices, while less connected choices are often labeled peripheral choices (Thompson 1967, Hannan and Freeman 1984, Singh et al. 1986, Levinthal and Posen 2007, Zott and Amit 2010). Take, for example, Ryanair's business model (Casadesus-Masanell and Ricart 2010). One of the core features of Ryanair's business model is the low-cost fare structure. This choice to position itself as a low-cost fare carrier influences (directly and indirectly) many other choices, such as its route plan, fleet, and so forth. Other choices, such as the choice to offer low commissions to travel agencies is a peripheral feature of Ryanair's business model.

If all choices are not equally connected, then the question of the implications of focusing search efforts on core choices naturally arises. A large but diverse body of literature speaks to this question, although many studies arrive at conflicting findings and conclusions (see, for instance, Ethiraj and Levinthal 2004a for a discussion). Within theoretical work, structural inertia theory (Hannan et al. 2003a, b) suggests that organizations should focus primarily on the improvement of peripheral choices because changes to core aspects of organizations are likely to threaten their survival. In contrast, theoretical work on search and adaptation (Siggelkow 2002, Denrell 2012, Baumann and Siggelkow 2013, Shepherd et al. 2017) and business model innovation (Zott and Amit 2010, Foss and Saebi 2017) mostly points to the potential advantages of focusing search efforts on core choices. Similarly, empirical research has generated mixed results, with some studies finding that core changes hamper organizational performance and survival (e.g., Hannan and Freeman 1977, 1984, 1989; Carroll 1984), while other studies find either little or no impact on performance and survival (e.g., Delacroix and Swaminathan 1991, Singh et al. 1986) or even provide evidence that core changes can be performance enhancing (e.g., Haveman 1992, Mitchell and Singh 1993).

Using an NK performance landscape model[1] (Kauffman 1993, Levinthal 1997), this paper seeks to enhance our understanding of what may cause these inconsistencies. To reconcile the inconsistencies, existing research has often adopted two broad strategies that we build on. First, prior research suggests that the effects of focusing on core choices may depend on (previously ignored) contingency factors at the level of the firm or in the environment (e.g., Greve 1999). We argue that conflicting findings and conclusions may arise because we have an insufficient understanding of how time horizon moderates the effect of focus on the efficacy of search efforts. For instance, structural inertia theory has assumed that the short-term effects of the change process are always detrimental, even if the long-term effects arising from the content of the change may be beneficial; yet empirical research has been unable to confirm such a uniform pattern and has again found mixed results (Delacroix and Swaminathan 1991, Carroll and Teo 1996, Dowell and Swaminathan 2000, Dobrev et al. 2001). Our study identifies a more complex performance pattern arising from the moderating effect of the time horizon, and by extension, the degree of environmental change. For example, while a focus on core choices is often beneficial in both the short and the long run, in the medium run, the implications may be the opposite.

Second, conflicting findings and conclusions may also arise because what constitutes core and peripheral elements has often been conceptualized differently across different literatures and even within the same literature (Hsu and Hannan 2005). For example, Hannan et al. (1996) define core choices as having a high degree of interdependence and peripheral choices as having no influence over other choices. However, they also propose a second more generic definition, "coreness means connectedness," implying that peripheral choices may not necessarily be completely unconnected. This definition has also been adopted in some of the literature on search and adaptation (Siggelkow 2002). In contrast, the business model literature and related streams of research often invoke the core–periphery distinction without providing a clear definition. As a result, Ethiraj and Levinthal (2004a) concluded that "as a field, however, we need greater conceptual clarity as to what constitutes core versus peripheral changes" (p. 412).

While the differences among these definitions may seem subtle at first, we argue that they are important because they may imply different structural properties of the system such as hierarchy[2] and decomposability[3] (Ethiraj and Levinthal 2004a, c; Simon 1962), which, in turn, have important implications for the efficacy of a focused search. As a result, focusing on core changes when the core is structured following one definition may have the opposite effect (e.g., negative performance implications versus positive performance implications) of focusing on core changes in structures following a second core definition. For example, with the narrow definition of core and periphery in Hannan et al. (1996), where only core choices affect other choices while peripheral choices affect no other choices, a focus on core choices is always superior to a focus on peripheral choices, independent of the time horizon. With this narrow definition, a system must also be hierarchical to be considered a core–periphery structure. Yet, once peripheral choices are not entirely independent (but instead may influence either other peripheral choices or core choices), a midterm liability may emerge—that is, in the medium term, a focus on the core underperforms a focus on peripheral choices. If peripheral choices are not entirely independent, the system may no longer be strongly hierarchical but instead what we call nearly hierarchical.

Thus, any conceptualization of the core–periphery distinction must not only take into account how connected choices are but also two characteristics of these connections: the direction of the connections (i.e., are the connections outgoing (connections of influence) or incoming (connections of dependence)) and the target of the connections (i.e., are they, for example, connecting a core choice to other core choices or to peripheral choices (and vice versa)). Depending on the configuration of these characteristics, a system may become (nearly) decomposable and/or (nearly) hierarchical, which, in turn, has important implications for the efficacy of a focused search.

Our analysis of the underlying mechanisms shows that focusing on core choices is a double-edged sword. On the one hand (and this the focus of, for example, structural inertia theory), searching core choices is more difficult and risky because of their higher degree of influence. A change to a core choice may improve its fit while simultaneously decreasing the fit of those choices that are influenced by this core choice. As a result, the risk of decreasing the overall performance is much higher for core changes than for peripheral changes. On the other hand (and this is the focus of much of the literature on business model innovation), if successful, changes to the core always offer greater rewards. With their higher degree of influence, they may (indirectly) affect many other choices, thereby amplifying the performance impact of any successful change.

In the short run, a focus on core choices is always superior to a focus on peripheral choices because the higher rewards of changing to core choices are dominant: Given a low level of overall adaptation early on, adaptations to the core and periphery are still almost equally likely to succeed. In the long run, performance differences between a focus on core or periphery only emerge if the system is not decomposable: If core and periphery are not interdependent, the two subsystems can be optimized independently. Which subsystem is optimized first has no long-run performance implications (Simon 1962, Baldwin and Clark 2000, Ethiraj and Levinthal 2004c, Baumann and Siggelkow 2013). If, however, the system is nondecomposable, a focus on core choices becomes superior even in the long run.

In the midterm, things become more complicated and depend on the relationship between the core and periphery. Search becomes more and more difficult and less likely to succeed for two basic reasons. First, once the system becomes more adapted, many opportunities for further improvements have been already exploited and, thus, local search becomes increasingly unsuccessful. Second, this effect is amplified for core choices—that is, choices that influence many other choices. Even if the modification of a core choice has a positive direct effect on performance, its implications for the other choices influenced by this change might be negative and, as a result, the combined performance effect might be negative. Thus, these rippling effects of interactions (Levinthal 1997) slow down the process of adaptation of core choices and may result in the emergence of a midterm liability of a focus on the core. This midterm liability can be alleviated or even overcome if core and periphery are organized hierarchical—in hierarchical system, there are strong benefits to focusing search and adaptive efforts to the subsystem at the top of the hierarchy (Simon 1962, Ethiraj and Levinthal 2004a, Ghemawat and Levinthal 2008).

Our arguments and results make important contributions to several literatures. First and foremost, we provide new insights into the implications of the core–periphery distinction for search and adaptation and help to provide much needed conceptual clarity on the core–periphery distinction (Hannan et al. 1996, Siggelkow 2002, Ethiraj and Levinthal 2004a, Hsu and Hannan 2005). Our findings may also help to reconcile an important tension between the classic research on structural inertia (Singh et al. 1986; Carroll and Hannan 2000; Hannan et al. 2003a, b) and the recent literature on business model innovation (Ries 2011, Foss and Saebi 2017) regarding the effects of core changes. Specifically, we extend the theoretical mechanisms of both literatures thereby allowing us to identify differing assumptions across the two bodies of literature and point to conditions when either of these perspectives are likely to hold in empirical research.

Theoretical Background

Organizations and Business Models as Systems of Interdependent Choices

Strategy and organizational researchers have long emphasized that the choices managers face are highly interdependent (Miller and Friesen 1984, Thompson 1967), and that these choices must therefore fit together for a firm to achieve high performance (Khandwalla 1973, Miller and Friesen 1984, Drazin and Van de Ven 1985, Levinthal 1997, Siggelkow 2002). Take, for example, research on business models and business model innovation. Business models are often conceptualized as complex, interdependent activity systems (Porter and Siggelkow 2008, Casadesus-Masanell and Ricart 2010, Zott and Amit 2010, Zott et al. 2011). Accordingly, a business model "can be characterized in terms of the interdependencies among the firm's value creation, delivery, and capture mechanisms and the underlying activities" (Foss and Saebi 2017, p. 216). Similarly, research on organizational ecologies focuses on (differences) in interdependencies among organizational choices to explain why organizations struggle to adapt and survive (Hannan and Freeman 1984; Hannan et al. 2003a, b).

Most research viewing organizations as systems of interdependent choices conceptualizes adaptation as a search process (Levinthal 1997; Hannan et al. 2003a, b; Zott and Amit 2010). Given the complexity of organizational environments and the cognitive limitations of organizations and organizational decision makers (Simon 1947, 1955, 1956, 1990), the complete set of alternatives and their performance implications are not known ex ante to the organization and its decision makers. Instead, these alternatives must be discovered and constructed through search activities. Organizations seek to enhance their performance by systematically searching for performance-improving alternatives (Levinthal 1997). Most organizational search for alternatives is local (March and Simon 1958, Cyert and March 1963, Katila 2002)—that is, due to limitations in cognitive resources, information, and time, only alternatives in the neighborhood of the organization's current position are searched. Furthermore, local search is facilitated by existing knowledge of the organization that enhances the learning of closely related knowledge (Nelson and Winter 1982, Laursen 2012). Empirical research on search has confirmed the central role of local search in a variety of contexts (e.g., Helfat 1994, Martin and Mitchell 1998, Laursen 2012).

Core-Periphery Structures in Systems of Interdependent Choices

To understand the efficacy of search and adaptation in organizations viewed as systems of interdependent choices, it is important to understand the structure of these systems in more detail. Empirical research on organizations as systems of interdependent systems (Sanchez and Mahoney 1996b, Baldwin and Clark 2000, Siggelkow 2002) suggests that not all choices in systems are equally interdependent and that interdependencies are not always symmetrical (or reciprocal) or randomly distributed. Instead, interdependencies often are distributed such that some choices are more central (or core) to the organization than other, more peripheral, choices (e.g., Hannan and Freeman 1984, Singh et al. 1986, Siggelkow 2002, Levinthal and Posen 2007, Zott and Amit 2010). Such core–periphery structures have been identified across several literatures, albeit with slightly differing terminology at times. For example, the strategy literature distinguishes between strategic and nonstrategic choices (Siggelkow 2002, Ghemawat and Levinthal 2008) or critical and noncritical choices (Ghemawat and Levinthal 2008), whereas in the business model literature, Zott and Amit (2010) distinguish between key and nonkey activities of the business model; finally, in the literature on organizational ecology and specifically structural inertia theory, Hannan and Freeman (1984) distinguish core from peripheral choices of the organization. In the following, we will use the terms core and peripheral choices.

In addition to varying terminology, there is an ongoing debate as to how to distinguish between core and peripheral choices in a system of interdependent choices. For instance, Hannan et al. (1996, p. 507) stated that while "there seems to be a general agreement that some organizational features fall nearer the core than others, we see no consensus on exactly what constitutes the core," raising the question of "what makes some features core and others peripheral" (Carroll and Hannan 2004, p. 62). Similarly, Ethiraj and Levinthal (2004a, p. 412) observed that "we need greater conceptual clarity as to what constitutes core versus peripheral changes" and Siggelkow (2002, p. 125) concluded that "while the distinction between core and non-core elements has become common in the organizational literature, little progress has been made to date in distinguishing them systematically."

While some early research built on a list of core features in an organization (e.g., Hannan and Freeman 1984, Romanelli and Tushman 1994), later, more abstract definitions draw on differences in interdependencies. Specifically, consistent with the notion of Hannan et al. (1996), Siggelkow (2002) defined coreness as connectedness—that is, an element is a core element if it interacts with many of the organization's other elements. To measure coreness, Siggelkow (2002) used different centrality measures and found that in his empirical setting, all four different centrality measures identified the same set of choices as core choices. In our study, we start our analysis from this definition of coreness as connectedness.

Efficacy of Focusing Search on Core or Peripheral Choices

While prior research is in broad agreement that organizations can be viewed as systems of interdependent choices that exhibit a core–periphery structure and adapt mostly through local search, it is inconclusive as to whether and how organizations should reflect this structure in the focus of their search efforts. For instance, research on search, learning, and imitation has often implicitly or explicitly argued for a focus on core choices (Siggelkow 2002, Denrell 2012, Baumann and Siggelkow 2013, Shepherd et al. 2017), yet has not systematically examined this argument. Research on business model adaptation and innovation has taken a similar view (e.g., Desyllas and Sako 2013, Girotra and Netessine 2014, Kim and Min 2015, Garcia-Gutierrez and Martinez-Borreguero 2016). Under the notion of business model "pivots" (Ries 2011), this research suggests focusing on searching core elements of an organization's business model to achieve substantial performance improvements. Research drawing on structural inertia theory in particular has come to the opposite conclusion, highlighting the potential risks of changes to the core (Singh et al. 1986; Haveman 1992; Barnett and Carroll 1995; Hannan et al. 2003a, b). This literature argues that organizations should focus attention on the improvement of peripheral choices as changes to the core choices of organizations are likely to require significant adjustments across a variety of interdependent choices, leading to a cascade of changes that create instability and may threaten the organization's survival. This logic was also widely adopted in the popular management literature of the 1990s and 2000s (e.g., Collins and Porras 1994, Zook and Allen 2003). Finally, empirical research is inconclusive. Some studies find core changes to hamper organizational performance and survival (e.g., Hannan and Freeman 1977, 1984; Carroll 1984; Hannan and Freeman 1989), whereas other find little effect (e.g., Delacroix and Swaminathan 1991, Singh et al. 1986) or even positive effects on performance and survival (e.g., Haveman 1992, Mitchell and Singh 1993). This inconsistency constitutes a "genuine unsolved puzzle concerning a central issue in the field" (Carroll and Hannan 2000, p. 370).

Decomposability and Hierarchy in Interdependent Systems. To resolve these contradictory findings, we start from the insight that not all systems that exhibit core–periphery structures are homogeneous with respect to other structural characteristics and that this heterogeneity may have important implications for the efficacy of search and focus. In structural inertia theory, the relationship between the core and periphery is often discussed under the labels of structural complexity[4] (Barnett and Carroll 1995, Hannan and Freeman 1984) or "organizational complexity" (Kelly and Amburgey 1991). Complexity theory (Simon 1962) points to decomposability and hierarchy as important structural characteristics of systems of interdependent choices.[5] In many cases, a complex system can be decomposed into (almost) independent subsystems. In any such system, one can distinguish interactions *between* subsystems (in our case, subsystems of core and peripheral choices) and *within* subsystems (Simon 1962, Ethiraj and Levinthal 2004c, Ghemawat and Levinthal 2008). A system without any interactions among the subsystems is fully *decomposable.* If interactions within subsystems are much stronger than between subsystems, a system may become nearly decomposable. A system with strong between interactions may become nondecomposable. If there are asymmetries in between-subsystem interactions—that is, one subsystem influences another subsystem but not the other way around—the system becomes *hierarchical* (Simon 1962, Ethiraj and Levinthal 2004a). Finally, with a near-hierarchical system, influence is mutual, but stronger in one direction than the other. Empirical research suggests that many real-world systems are often more or less decomposable (i.e., near decomposable) and hierarchical (i.e., near hierarchical); systems such as computer code (MacCormack et al. 2012), computer systems (Baldwin and Clark 2000), gas turbines (Sharman and Yassine 2003), and organizations (Sanchez and Mahoney 1996b, Langlois 2002) and their business models (Siggelkow 2002, Ghemawat and Levinthal 2008) have been described as near-decomposable and near-hierarchical systems.

In the context of this study, (near-)decomposability and (near-)hierarchy may be central for a more nuanced understanding of the implications of focusing search on core or peripheral choices because they have implications for search. (Nearly) decomposable systems are much easier to search and optimize than nondecomposable systems since in a decomposable system, each subsystem can be searched and optimized without implications for other subsystems (Simon 1962, McDonald and Eisenhardt 2017). With strong between-subsystem interactions, the system may become nondecomposable and difficult to search and optimize. Similarly, while between-subsystem interactions that characterize hierarchical systems may complicate the search process, they also imply a clear hierarchy in search priorities (Simon 1962). The subsystem at the top of the hierarchy should be optimized first, followed by subsystems at the bottom of the hierarchy. As a result, Ghemawat and Levinthal (2008) suggest that core choices (or in their terms, "critical choices") are those higher up in the hierarchy. Choices at the top of the hierarchy—that is, choices that affect the optimal configuration of other, lower-level choices—are particularly important to search and adapt accurately early in the process (Ethiraj and Levinthal 2004a, Ghemawat and Levinthal 2008, Simon 1962). Hannan and Freeman (1984) also conclude that hierarchical structures are easier and faster to change than nonhierarchical structures. For example, in their account of educational reforms, Hannan and Freeman (1989) describe how a lack of hierarchical structure inhibited change.

Past definitions of the core–periphery distinction often differ in the extent to which they imply either decomposability or hierarchy. Take, for example, the definition put forward by Hannan et al. (1996). They argue that "a feature forms part of the organizational 'core' if changing it requires adjustments in most other features of the enterprise. A feature lies at the periphery if it can be changed without imposing changes on other features" (Hannan et al. 1996, p. 506). With this definition, hierarchical, nearly hierarchical, and non-hierarchical systems might be all categorized as core–periphery systems. Hannan and Freeman (1989) are even more explicit, suggesting that "changes in the core structures usually require adjustment in the peripheral structures. However, the reverse is not true" (p. 79). Put differently, this definition implicitly suggests that core and peripheral choices are embedded in a (more or less) decomposable and (strongly) hierarchical system: the subsystem of core choices exhibits strong within-core interactions while the subsystem of peripheral choices exhibits no within-periphery interactions. Peripheral choices do not influence core choices, while core choices may influence peripheral choices. In contrast, Siggelkow's (2002, p. 127) definition of an organization's core and periphery makes fewer assumptions about the system's structural characteristics: "Coreness means connectedness, elements in the core are linked in complicated webs of relations with each other and with peripheral elements. Thus, an element is core if it interacts with many of the organization's other elements." Such a definition does not imply decomposability or hierarchy.

In more abstract terms, on the one hand, systems with core–periphery structures may exhibit important heterogeneity in terms of decomposability and hierarchy, heterogeneity that may not be picked up by existing conceptualizations of core–periphery distinctions and measures, despite the fact that these aspects are known to have strong implications for search. On the other hand, heterogeneity in terms of decomposability and hierarchy may result in some structures being classified as core–periphery structures according to certain conceptualizations but not others.

Time Horizon and Environmental Change. An important contingency for the effect of focus on the efficacy of search may arise from the time horizon of performance effects, and by extension, environmental change. From past research, we know that long-run advantages often come at some cost in the short or medium term (see also Puranam et al. 2015, Siggelkow and Levinthal 2003, or Levinthal and Posen 2007 for more details). Similarly, in their original work on structural inertia, Hannan and Freeman (1984) speculate that core changes often have negative short-term effects even when they may have long-term benefits; however, these long-run benefits are often irrelevant because the short-term disadvantages may prevent organizations from surviving in the long run. Based on the comparison of more or less decomposable systems, Baldwin and Clark (2000) concluded that "neither modular designs nor interdependent designs are inherently superior; the costs and benefits of each approach vary by case and *over time*" (p. 258, italics added by the authors). Any long-run advantage may also be irrelevant in changing environments because they may "never occur in this particular environment—the environment will have changed by then" (Csaszar and Siggelkow 2010, p. 664). Environmental changes may alter the returns to a wide range of policy alternatives, for instance, due to changes in macroeconomic conditions, regulation, or radical technological change (Anderson and Tushman 1990), Thus, in an environment characterized by high degrees of change, firms would face different environments frequently and only would be interested in performance improvements that can be achieved before change makes adaptations obsolete. This mechanism is also one of the drivers behind the *liability of aging* (Barnett 1990, Barron et al. 1994). Age may not have any effect on mortality per se; "instead, age tracks the fit between an organization and its environment" (Hannan 1998, p. 158). Implicit in this logic is the assumption that environments are not static but dynamic (Hannan and Freeman 1989). Indeed, Hannan and Freeman (1984) have always defined (core) inertia *relative* to the extent of environmental change: "Structures of organization have high inertia when the speed of reorganization is much lower than the rate at which environmental conditions change" (p. 151). In sum, while there is much consensus that most organizations operate in dynamic environments and that the time horizon (and its cousins: age, life cycle, maturity) has important implications for the efficacy of searching core elements, empirical research has been unable to generate consistent evidence for the moderating effect of the time horizon (and, by implication, environmental change) on the efficacy of core changes (Delacroix and Swaminathan 1991, Carroll and Teo 1996, Dowell and Swaminathan 2000, Dobrev et al. 2001).

Model

To examine the implications of focusing search efforts for organizational adaptation and performance, we extend a standard NK model (e.g., Ethiraj and Levinthal 2004a, Ganco and Hoetker 2009, Kauffman 1993, Levinthal 1997, Rivkin 2001, Siggelkow and Rivkin 2005). The standard NK performance landscape model has three basic features: (1) a complex performance landscape, (2) an organization that is represented by a position on this performance landscape, and (3) a (local) search process that the organization uses to adapt and improve its position on the performance landscape. In the basic NK performance landscape model, the searching organization exhibits uniform attention: it searches with equal probability in all directions of the landscape. We extend the standard NK performance landscape model by relaxing the latter assumption about uniform attention and examining focused search processes that are guided by a cognitive representation of the problem structure.

Complex Performance Landscapes

The starting point of our model is an $\boldsymbol{N}$-dimensional activity vector $\mathbf{a} = (a_1, a_2,\ldots, a_N)$ of binary policy choices $a_i \in 0{,}1$ with $i \in I = 1,\ldots, N$, yielding a total of 2^N possible combinations of choices. We interpret the vector $\mathbf{a}$ as representing an organization's configuration of policy choices or activity system. The degree of interdependence among an organization's policy choices is determined by the parameter $\boldsymbol{K} \in \{0,\ldots, N-1\}$, which describes the number of choices a_j that (co) determine the performance effect of policy choice a_i. This effect is characterized by the contribution function $c_i = c_i\,(a_i, a_{i1}, a_{i2},\ldots, a_{iK})$, where $i_1, i_2,\ldots, i_K$ are K policy choices that are distinct from i. The realizations of the contribution function are drawn from a uniform distribution over the unit interval $c_i \sim U[0;1]$. The performance of a given policy-choice vector $\mathbf{a}$ is calculated as the arithmetic mean of the N contributions c_i according to the performance function $\phi =$. Thus, a "landscape" represents a mapping of all 2^N possible outcomes of the policy-choice vector onto performance values. We normalize each landscape to the unit interval such that the mean value of the normalized landscape equals 0.5 and the global maximum equals 1.0. The "local peaks" on the performance landscape represent policy-choice vectors for which an organization cannot improve its performance through local search (Levinthal 1997). The "global peak" is the highest peak in the landscape.

The parameter K is interpreted as a measure of complexity. The lowest value, $K = 0$, implies that policy choices do not depend on each other and yields a smooth performance landscape with a single (global) peak; the highest value, $K = N - 1$, implies that each policy choice depends on all other choices, yielding a rugged landscape. In the standard NK performance landscape model, all choices exhibit the same level of interdependence (i.e., K). Such random landscapes do not exhibit a core–periphery structure.

In our extension, choices may vary in the extent to which they are connected to other choices: not all choices are equally connected, and these connections may not necessarily be symmetric and reciprocal. They may also be denser within subsystems than between subsystems. In the extreme case of an absence of any between-subsystem connections, the system becomes decomposable. Once connections are not entirely random, it also becomes important to take into account their directionality (see Ghemawat and Levinthal 2008 for more a more detailed exposition)—that is, to distinguish between whether a choice is influencing other choices or is influenced by other choices. Only if there are asymmetries in interdependencies may a hierarchy of choices emerge (Simon 1962).

In our experiments, we start from a definition of "coreness means connectedness"—that is, core choices are assumed to exhibit more connections (ignoring the direction) than peripheral choices. We further refine this definition by taking into account both the direction of connections (influence[6] versus dependence) and which choices are influenced by connections, resulting in the distinction of within-core or between core–periphery influences. We adopt a procedure from Knudsen and Levinthal (2007) to generate interaction matrices with a core and periphery structure: we divide the interaction matrix into four equally large quadrants. These quadrants may differ in their complexity K. The first eight choices are considered core choices; the second eight choices are peripheral choices. The top left quadrant reflects the interdependencies within the core (K_C), and the bottom right quadrant reflects the interdependencies within the periphery (K_P). Both K_P and K_C can take values between 0 and 8, and $K_P < K_C$. Interdependencies between the core and periphery are measured by the parameters K_{CP} and K_{PC}—that is, the extent to which the core influences the periphery and vice versa.

Local Search and Focus to Core or Periphery

To improve performance, organizations are assumed to engage in a local hill-climbing search process (Holland 1975, Levinthal 1997). In the standard NK performance landscape model, the local search is typically modeled as an offline search (Knudsen and Levinthal 2007, Winter et al. 2007) and involves randomly selecting one of the N choices and inverting its value. Offline search implies that organizations evaluate the implication of changes based on thought experiments, simulations, or relatively cheap and noninvasive experiments such laboratory studies, or pilot plants (Winter et al. 2007). Compared with distant search, the offline evaluation of changes of local changes is often regarded as relatively precise (Levinthal 1997). Thus, in our model, if the new policy-choice vector yields a higher performance, the change is retained (i.e., the choice vector is modified), and the search continues from this new vector in period $t+1$. Otherwise, the new choice vector is discarded (i.e., the choice vector is not modified), and the next search step starts from the unchanged vector defined in period t. Pursuing a local hill-climbing search, the organization will eventually converge to a policy-choice vector from which performance cannot be improved by modifying one of the N policy choices (i.e., a local or global peak). Unlike with global search, with local search, it seems to be more likely that the immediate performance implications of just one policy choice change can be anticipated. Furthermore, with local search, organizations can even benefit from evaluation errors—that is, deviations from strictly hill-climbing. This is particular true if these errors are not completely random but a function of the fitness differences (Knudsen and Levinthal 2007)—that is, if they affect core choices differently than peripheral choices. Thus, our results based on strictly hill-climbing reflect a conservative estimate of the implications.

In the standard NK simulation model (Levinthal 1997), all N choices of an organization receive the same attention in the local search process; that is, all N choices have the same probability of becoming the subject of the local search process. In our study, we relax this assumption by allowing some choices to receive more attention than others; in other words, some choices have a higher likelihood of being explored than others. Specifically, in each period t, with probability $p \in [0,1]$ the organization constrains its local search to the $N/2$ core choices [and with probability $(1 - p)$, it constrains it to the $N/2$ peripheral choices]. All choices in the chosen subset have the same probability ($p = 2/N$) of becoming the focus of attention in the local search process. In our experiments, we assume a strong but nonexclusive focus on core choices: p is set to $2/3$—that is, each core choice receives 2 times more attention than each peripheral choice. With a nonexclusive focus of $p = 2/3$, it is guaranteed that organizations converge to either a local or global peak within 200 periods.

Analysis

In the following subsections, we report results for the case of a performance landscape with $n = 16$ and various core–periphery structures. Each experiment involves 200,000 independent simulation runs. Consistent with prior modeling efforts, in each simulation run, the organization begins its search from a random position on the landscape. To conserve space, we first present the key findings of our analyses and then the intuition underlying the results. Additional experiments, robustness analyses, and further technical discussion can be found in the online appendix.

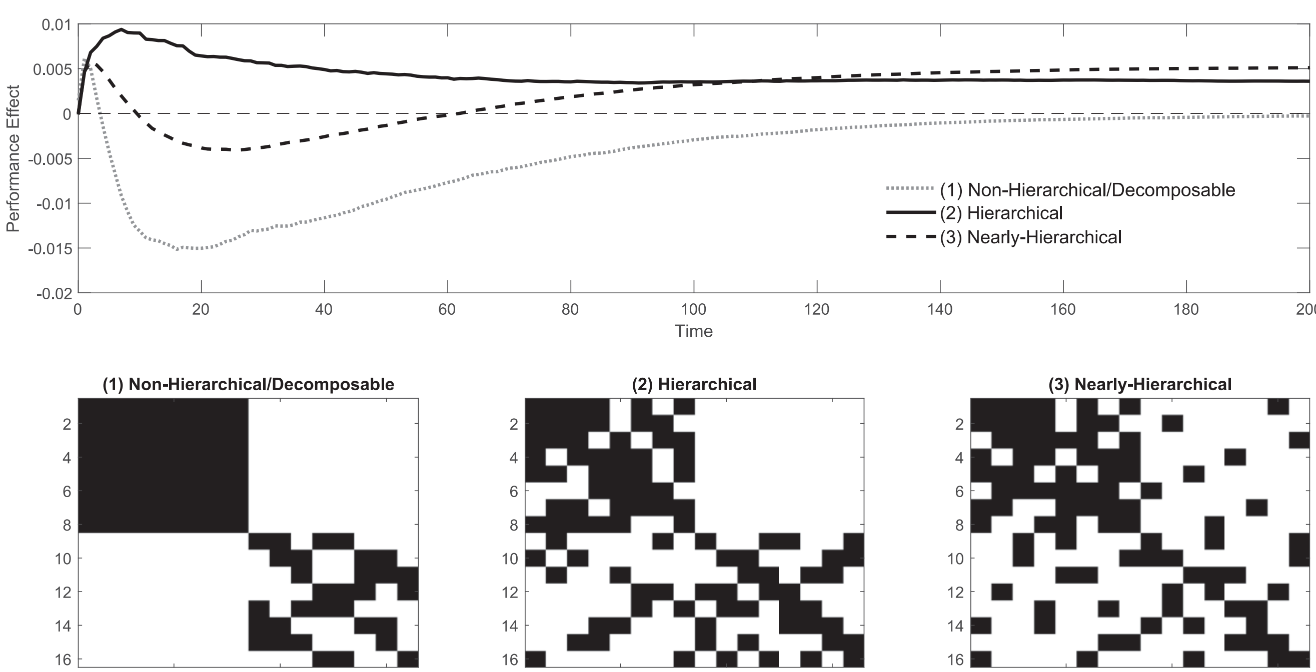
Main Result: Different Time Horizons and Different Core–Periphery Structures

In the first set of analyses, we investigate the implications of focusing attention on core or peripheral choices for different types of core–periphery systems and different time horizons. In Figure 1, we plot the differences in performance between search that focuses on a system's core choices and that focuses on peripheral choices as a function of time (x-axis). Positive values imply that a focus on core choices is superior to a focus on peripheral choices; negative values imply that a focus on core choices is inferior to a focus on core choices. Recall that search is strictly hill-climbing in our model, and therefore organizations can only maintain their performance or improve. In other words, a positive performance difference arises from a higher performance improvement following a core choice change and can never be the result of a smaller performance reduction compared with a peripheral choice change as such changes are not being executed in offline search.

In our first experiment, we are interested in how hierarchy in core–periphery structures may affect the efficacy of focused search processes. We distinguish between hierarchical and nearly hierarchical systems. In hierarchical systems, one subsystem influences another, but not the other way around. In nearly hierarchical systems, both subsystems influence each other, but the influence is not equally strong in both directions: one subsystem has a stronger influence over the other. For the sake of a baseline comparison, we also include the results of a decomposable (and, by implication nonhierarchical) system. We investigate the efficacy of focused search for different time horizons. As suggested by prior research, a search mechanism that is superior in the long run is not necessarily superior in the short run (March 1991, Levinthal and Posen 2007, Puranam et al. 2015). This trade-off between short- and long-run performance is important because even if there are positive long-run performance effects, this might be irrelevant under many circumstances (Eisenhardt 1989, Stalk and Hout 1990, Nayyar and Bantel 1994), particularly when frequent environmental changes may make prior adaptive choices obsolete.

In nearly hierarchical systems, a focus on core choices is superior to a focus on peripheral choices in both the short run and the long run (dashed black line). In the medium run, however, this result is reversed and firms can be better off focusing on

Figure 1. Effect of Core–Periphery Relationship



Notes. In the top panel, we report the performance difference between focus on core choices (pH = 2/3) and peripheral choices (pH = 1/3)—that is, core choices receive twice as much attention as peripheral choices—for different core–periphery structures. For all three core–periphery structures, each core choice influences seven other choices while each peripheral choice influences three other choices (i.e., $K_{CP} + K_C = 7$ and $K_P + K_{PC} = 3$). In the case of the decomposable structure (1), core choices influence only other core choices ($K_C = 7$ and $K_{CP} = 0$) and peripheral choices influence only peripheral choices ($K_P = 3$ and $K_{PC} = 0$). In the case of a hierarchical structure (2), each core choice influences five other core choices and two peripheral choices ($K_C = 5$ and $K_{CP} = 2$). Peripheral choices, in contrast, only influence other peripheral choices ($K_P = 3$ and $K_{PC} = 0$). In the case of a nearly hierarchical core–periphery structure (3), each core choice influences two peripheral choices ($K_C = 5$ and $K_{CP} = 2$), while each peripheral choice only influences one core choice ($K_P = 2$ and $K_{PC} = 1$).

peripheral choices than on core choices. In contrast, with a (strongly) hierarchical system—that is, core choices influence peripheral choices but not the other way around (black solid line)—it is better to focus on core rather than peripheral choices for all time horizons. Finally, if the system is nonhierarchical and decomposable—that is, the core and periphery do not interact with each other (gray pointed line)—there will be no long-run performance differences between a focus on the core and periphery, but advantages to a focus on the core in the short run and disadvantages to such a focus in the medium run. In more abstract terms, the time horizon and the nature of the interaction between the core and periphery are important determinants of the efficacy of search. In the following subsection, we seek to further enhance our understanding of how the exact nature of the interaction between the core and periphery may affect the efficacy of focused search.

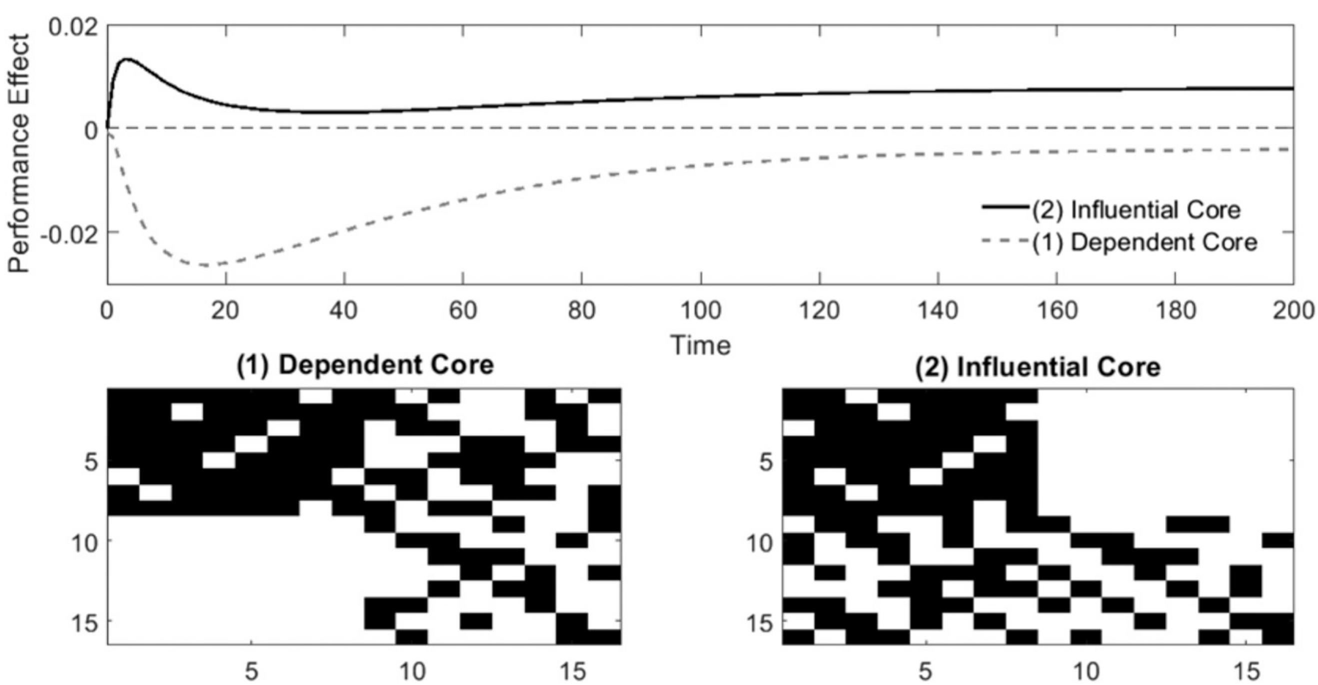
Direction of Connections and the Target of Influence

Our first set of results suggests that any definition of core choices that relies solely on the number of connections may ignore structural aspects of core–periphery structures. In all of the systems analyzed above, core choices are much more connected than peripheral choices. Yet, the implications for the efficacy of search are quite different, suggesting that the direction of connections may also matter: Are choices influencing other choices, or are they influenced by other choices? As highlighted by prior research, the direction of connection has important implications for both the characteristics of the resulting performance landscape (Rivkin and Siggelkow 2007) and the efficacy of different search mechanisms (Ghemawat and Levinthal 2008, Baumann and Siggelkow 2013).

Consider the two illustrative cases of core–periphery structures depicted in Figure 2. In both systems, each core choice has connections to 7 + 15 = 22 (i.e., sum of in- and out-degrees) connections to other choices, while peripheral choices are connected to only 8 + 2 = 10 choices. Any empirical measure that simply counts the number of connections would classify the first eight choices as core choices and the second eight choices as peripheral choices.

The implications for search efficacy, however, are substantially different: For the first structure, a focus on core choices is superior to focusing on peripheral choices in both the short and long run. In the medium run, however, a midterm liability emerges. In contrast, for the second structure, a focus on core choices is inferior to a focus on peripheral choices for

Figure 2. Direction of Connections



Notes. In the top panel, we report the performance difference between focus on core choices and peripheral choices ($pH = 2/3$ versus $pH = 1/3$) for two core–periphery structures. For both structures, the core is more connected than the periphery ($K_C = 7$ versus $K_P = 2$) and the number of connections of the core is identical ($K_{C\cdot} + K_{CP} + K_{PC} = 11$). Yet, for structure 1, the core depends on the periphery ($K_{CP} = 0$ and $K_{PC} = 4$), while with structure 2, the core influences the periphery ($K_{CP} = 4$ and $K_{PC} = 0$).

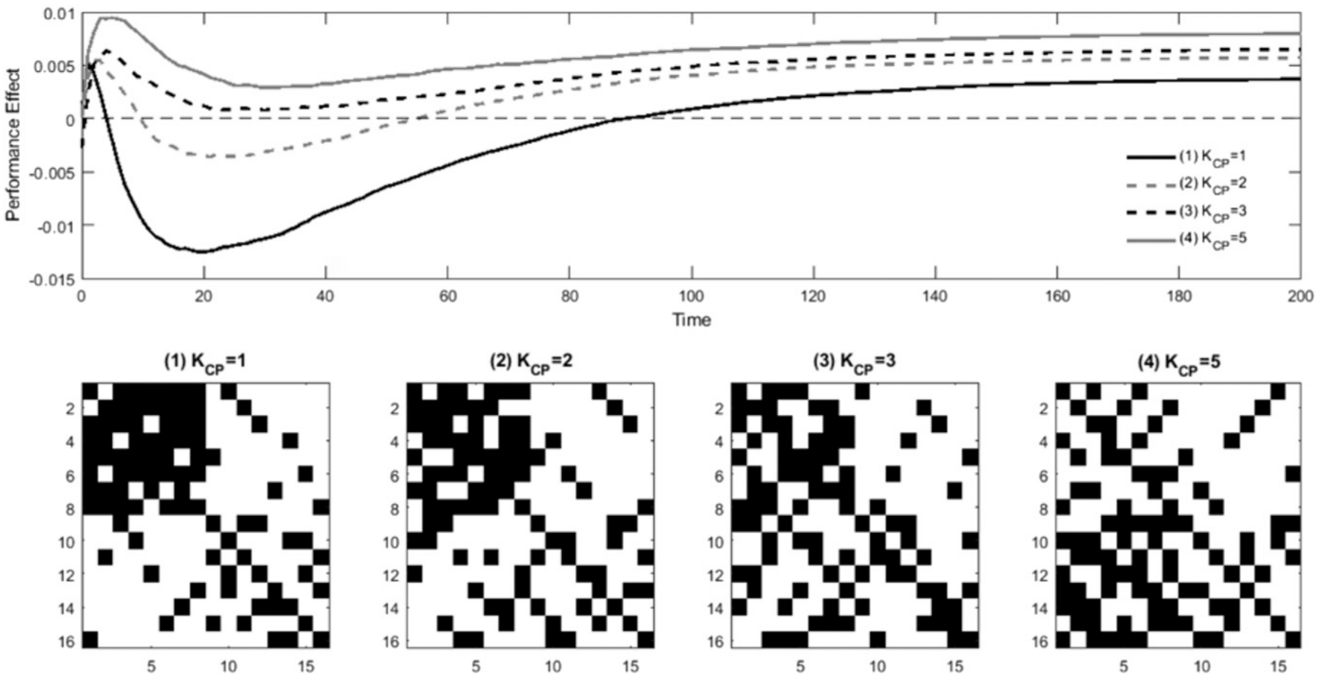
all time horizons. The two structures are identical in the number of connections that core (peripheral) choices exhibit, but they differ in the extent to which these connections are connections of influence or dependence. In the first system, core choices influence all other choices—both core and peripheral choices. In the second system, core choices depend on all other choices. Thus, the direction of connection is important to understand the efficacy of focused search.

In the next step, we focus on systems in which we hold constant the number of choices each core choice influences and only vary the target of influence—that is, influential or noninfluential choices. In all four systems reported in Figure 3, each core choice always influences eight other (core or peripheral) choices ($K_C + K_{CP} = 8$), while peripheral choices always influence only four other (core or peripheral) choices, of which one is a core choice ($K_{PC} = 1$). These four systems only differ in the extent to which core choices affect other core choices ($8 - K_{CP}$) or peripheral choices (K_{CP}). With $K_{CP} = 1$, the system is neither hierarchical nor decomposable (reciprocal interdependence). With $K_{CP} > 1$, the system is nearly hierarchical—that is, the core has a stronger influence on the periphery than vice versa. Analogous to Figure 1, we report the performance effect of focusing on core choices.

Despite the fact that core choices are always equally influential across all four systems, different performance patterns emerge. In the short and long run, a focus on core choices is always superior to a focus on peripheral choices. Yet, in the midterm, a focus on the core is only superior if there is a strong influence on peripheral choices; if the influence on peripheral choices is weak (and core choices strongly influence other core choices instead), a midterm liability emerges. These results suggest that in conceptualizing the core–periphery distinction, it is also important to consider the target of influence—influential (core) choices or less influential (peripheral) choices.

Taken together, these findings regarding the time dependence of the focus and different structures of core and periphery systems are important for three reasons. First, they suggest that extant core–periphery distinctions are still underconceptualized. Consistent with the definition of "coreness means connectedness," existing empirical research may systematically subsume systems with fundamentally different structural characteristics under the same label. By focusing solely on the differences in the number of connections, they fail to take into account the direction of connections and the targets of connections. These characteristics, however, are important determinants of

Figure 3. Target of Influence



Notes. In the top panel, we report the performance difference between focus on core choices and peripheral choices ($pH = 2/3$ versus $pH = 1/3$) for four core–periphery structures. For all structures, core choices influence seven other choices ($K_C. + K_{CP} = 7$); the structures vary, however, in the extent to which core or peripheral choices are influenced, ranging from influencing predominately other core choices ($K_C = 6$ and $K_{CP} = 1$) to influencing predominately peripheral choices ($K_C = 2$ and $K_{CP} = 5$).

the extent to which a system is hierarchical and decomposable, which, in turn, are important drivers of the efficacy of focused search.

Second, existing conceptualizations are inconsistent in the way they classify systems. For example, in the narrow definition of Hannan et al. (1996), only the hierarchical systems we analyzed exhibit a core–periphery structure; all other systems are not considered core–periphery structures. According to the second, more generic definition of Hannan et al. (1996) (i.e., coreness means connectedness), both the decomposable and nonhierarchical systems above also exhibit a core–periphery structure. This is problematic because the efficacy of focused search is driven by the extent to which a system is hierarchical and decomposable.

Third, our findings point to the importance of a more nuanced consideration of the time horizon in understanding the implications of focused search in core–periphery structures. Our results suggest that there is considerable variation in the efficacy of search across different time horizons and that this variation is much more complex than the well-known trade-off between short- and long-run efficacy.

Mechanisms Driving the Efficacy of Focusing Search

In the standard NK performance landscape model (Levinthal 1997), we observe low long-term performance if local search makes organizations prematurely converge to a local (rather than the global) peak. The efficacy of search can be improved by inducing more exploration through, for example, (1) searching more distant alternatives by changing more than one choice at a time (e.g., Csaszar and Siggelkow 2010, Levinthal 1997) or (2) by adopting, at least temporarily, inferior solutions to move toward an alternative (and hopefully better) peak. For example, organizations may adopt inferior solutions because they may suffer from evaluation errors (Knudsen and Levinthal 2007) or control losses (Levinthal and Workiewicz 2018, Puranam 2018). With its focus on how to retain and introduce exploration, existing research often frames the primary challenge of search as one of dislodging organizations that became stuck on a local peak in the performance landscape by introducing some nonlocal search mechanism (Gavetti 2012).[7]

In our model, however, these two mechanisms of exploration are absent: regardless of a firm's focus, the firm always only searches locally (i.e., only one choice is changed at a time) and it only accepts modifications that improve organizational performance; that is, search is offline and therefore strictly hill-climbing, whereas with online search also performance decreasing changes might be implemented. Thus, in contrast to the emphasis of existing research on the need to balance exploitation and exploration, the mechanism generating our results is one of affecting the efficacy of local search (or exploitation).

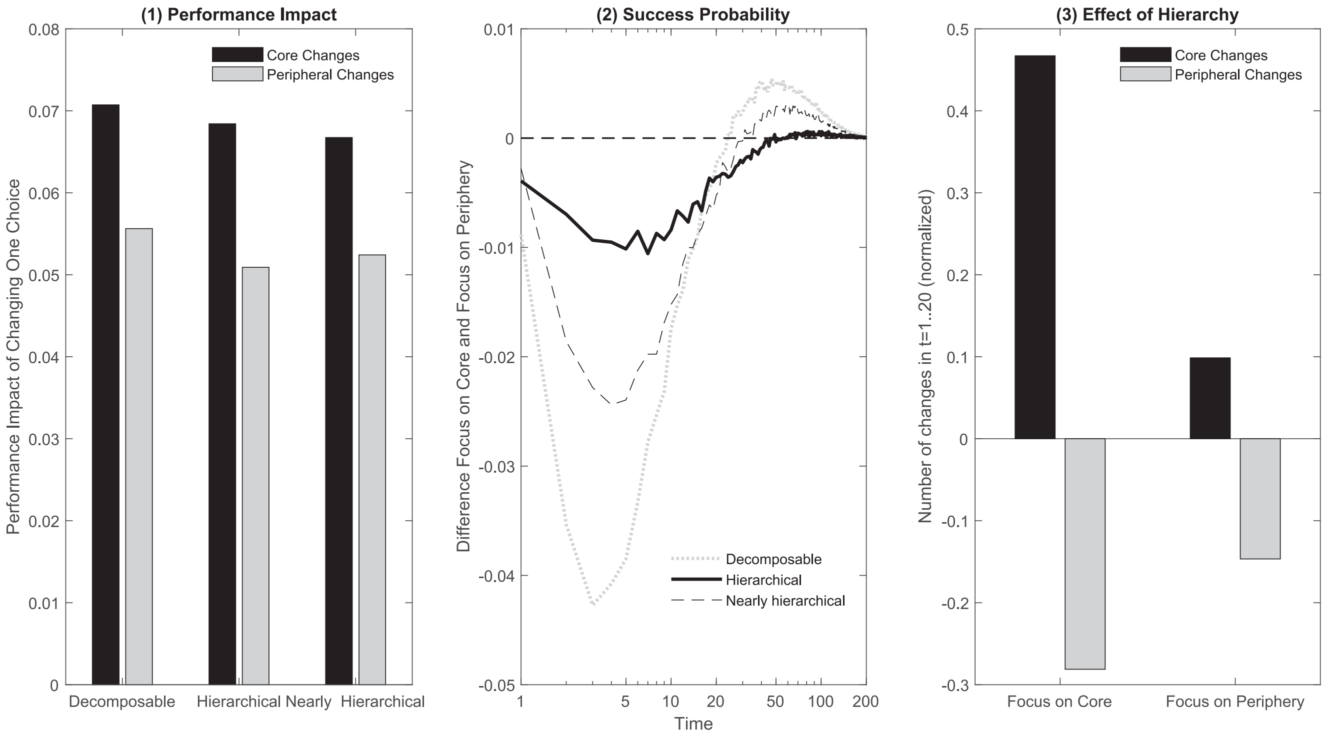
Two opposing forces drive the efficacy of search in our model. Changes to core choices offer higher rewards than changes to peripheral choices (Levinthal and March 1981) because the influence that core choices exert on other choices may amplify their performance effect. Influential choices have both direct effects and indirect effects (via the choices they influence) on the system's performance; choices that do not influence other choices only have a direct effect on performance. All else equal, the performance impact is an increasing function of a choice's influence—that is, the number of other choices it influences. Early on, when the organization is not yet very well adapted, this higher performance impact is the main driver for the superiority of a focus on core choices.

Take for instance the results of Figure 4 (panel A), where we compare the average rewards of core and peripheral changes for the three core–periphery structures of Figure 1. The rewards of (successful) changes to core choices are substantially higher (around 30%) than those of peripheral changes for all three core–periphery structures. However, since performance improvements are rather independent of the core–periphery structure, differences in these performance improvements cannot be the sole determinant of variations in the implications of a focus on core or peripheral choices.

There is also a downside of searching core choices. The higher returns to successful changes to core (i.e., influential) choices come at a cost—a higher risk of failure (or a lower probability of success). Panel B of Figure 4 reports the differences in the probability of success for a search focus on core and peripheral choices across the three core–periphery structures. In the midterm, focusing on core choices is less likely to be successful than focusing on peripheral choices, while in the long run, the opposite is true. As highlighted in prior studies (e.g., Levinthal 1997, Ethiraj and Levinthal 2004a), the presence of interactions among choices slows down the process of adaptation and it takes longer for the process to converge. Core choices are particular susceptible to this problem, while the process of adapting peripheral choices is less affected. Because (successful) changes to the core become increasingly difficult, in the midterm, a focus on core choices exhibits a lower success probability and a midterm liability of focusing on core choices emerges for nonhierarchical or nearly hierarchical systems.

To understand why the midterm liability disappears for hierarchical systems, we have to understand how the core–periphery interdependencies affect the

Figure 4. Risk and Rewards in Focused Search



Notes. In left panel we report the average performance impact of successful changes to core or peripheral choices. In middle panel we report the differences in success probability between a focus on core choices and peripheral choices ($p = 2/3$ versus $p = 1/3$). Positive values imply that a focus on core choices is more likely to be successful than a focus on peripheral choices. In right panel we report the number of core and peripheral changes in the first 20 periods for a hierarchical core–periphery structure. We normalize these values by subtracting the corresponding values for a decomposable structure. Positive values imply that a hierarchical structure results in more core (peripheral) changes than a decomposable structure; negative values imply the opposite.

adaptability of the core and periphery. In Figure 4 (panel C), we report the number of successful core (black bars) and peripheral (gray bars) changes for hierarchical core–periphery structures in the first 20 periods (i.e., the period when the midterm liability is particularly pronounced). We normalize the effect by subtracting the number of successful changes in a completely decomposable system and report the results for a focus on core and peripheral choices. Recall that in our analyses, we hold constant the number of choices core and peripheral choices influence, independent of the core–periphery structure. In a hierarchical system, core choices influence both core and peripheral choices. In a decomposable system, in contrast, core choices only influence other core choices. In both systems peripheral choices only influence other peripheral choices.

If a core choice influences peripheral choices (but not vice versa), any adaptation of the core choice may require the subsequent adaptation of the affected peripheral choices. Yet, the latter adaptations do not trigger any further adaptations to the core again. In contrast, the influence of a core choice on other core choices will require changes to the other affected core choices, which, in turn, may require further changes to other core choices and so on. Thus, all else equal, changing core choices is less difficult if core choices influence peripheral choices (like in hierarchical systems) rather than only other core choices (like in decomposable systems). In line with this argument in Figure 4 (panel C), we observe a positive effect on the number of successful changes to core choices in hierarchical systems, for both a focus on core and peripheral choices. The net effect of suppressing peripheral changes and encouraging core changes is much more positive for a focus on core choices and, as a result, the midterm liability of a focus on the core can be more than compensated in hierarchical systems.

Finally, the core–periphery interdependencies are also the main driver behind any long-run performance differences. There are no long-run performance differences if core and periphery are independent. The two subsystems can be optimized independently because which subsystem receives more attention and is optimized first has no long-run performance implications (Simon 1962, Ethiraj and Levinthal 2004b). If a system is not decomposable, progress in the core inhibits progress in the periphery and vice versa. However, the costs of this coupling to overall performance are asymmetric because of the higher performance impact of every change to core choices. In other words, when core and periphery are interdependent, suppressing adaptations to the core (through a focus on peripheral choices) is more costly than suppressing adaptation to peripheral choices (through a focus on core choices) and therefore a focus on core choices results in higher long-run performance.

The Moderating Effect of Environmental Change

The experiments in the previous section illustrated that the time horizon may have a nontrivial impact on the effect of focus. These results also have important implications for our understanding of the effect of focus in turbulent environments. For example, any long-run implications might be irrelevant if the underlying performance landscape is changing frequently (for more details on the relationship between time horizon and environmental change, please see Csaszar and Siggelkow 2010). Then, the only relevant implications are those in the short and medium run because the environment may already have changed before the long-run implications played out. In this section, we investigate the effects of different types of environmental change. To limit the complexity of the analysis, we focus exemplarily on one core–periphery structure—that is, nonhierarchical and nondecomposable system core–periphery structure. The effects of alternative core–periphery structures follow analogously from the results regarding different time horizons.

To understand the effect of environmental changes for a focused search, it is useful to distinguish multiple dimensions of environmental change. Environmental change may vary in its magnitude and frequency (Dess and Beard 1984, Miller 1987, Baum and Wally 2003). More importantly, for our study, environmental change may also differ in how pervasively it changes the structure of the environment. Some environmental changes may alter the performance landscape but leave the underlying interdependence structure unchanged—that is, they may leave unchanged what constitutes a core or peripheral choice. We refer to such changes as "non-architectural changes" (as, for example, in Siggelkow and Rivkin 2005). Other environmental changes, however, may also alter the interaction structure (as, for example, in Ethiraj and Levinthal 2004a)—that is, what constitutes a core or peripheral. We call this "architectural change."

Both architectural change and nonarchitectural change may result in an environment that is distinctly different from the one the firm faced prior to the change. With architectural change, however, a focus on the core also turns into a focus on the periphery after an architectural change event. Thus, if a firm began by focusing on core choices, an architectural change event turns these core choices into peripheral choices, and vice versa; as a result, the firm may inadvertently find itself focusing on peripheral choices.

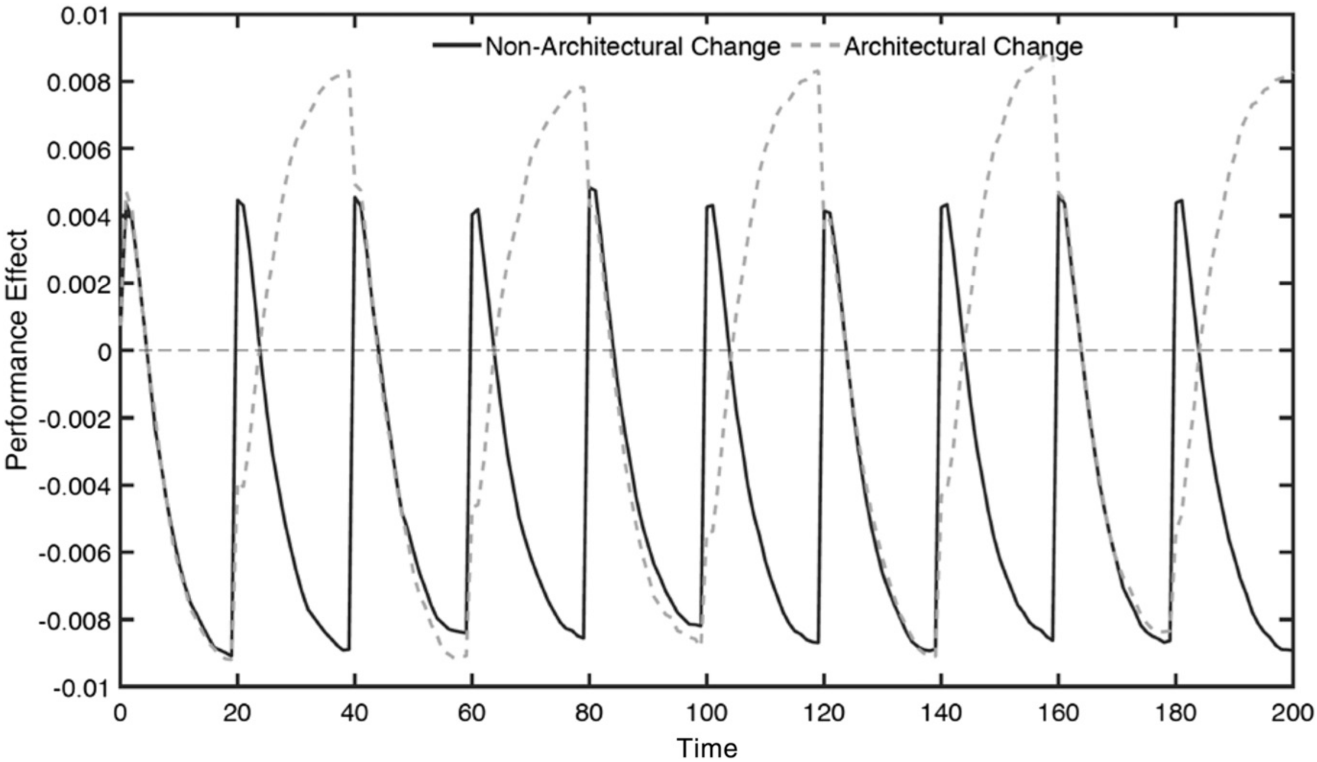
In Figure 5 we plot the performance differences that result from focusing on core choices and peripheral choices in turbulent environments. Specifically, we assume that a nonarchitectural (solid black line) or architectural change (dashed gray line) occurs every 20 periods.[8] Consistent with prior modeling efforts (e.g., Siggelkow and Rivkin 2005), we assume that the postshock landscape is completely different from the preshock landscape (i.e., that their correlation is zero). In the case of a nonarchitectural change, the shock may change the performance landscape but not the underlying core–periphery structure. As a result, the firm faces a new landscape every 20 periods, and all preshock adaptations are worthless after the shock; basically, the firm must start its search from a random position after each shock (as it did in period $t = 0$). From Figure 1, we can directly deduce the implications of nonarchitectural environmental changes for this type of change, as well as for more or less frequent environmental changes: early on (after each environmental shift), there is a positive effect of focus on the core; however, this effect becomes negative later on (or at the time that represented the medium term in Figure 1). This pattern repeats itself after each environmental shift.

For architectural changes, we observe a slightly different pattern. With every architectural change event, an organization's focus in the search processes also changes. If the search was focused on the core, it changes to a focus on the periphery (and vice versa). What was once a peripheral choice may become a core choice, and vice versa. Let us assume that a fundamental shock occurs every 20 periods—that is, all core choices become peripheral choices, and vice versa. After the second (fourth, sixth, and so on) shock, the cognitive representation is again correct. Thus, after the first shock, we observe a dynamic opposite to the one we observe after the second shock (and so on)—early after the shock, a focus on the periphery is better than a focus on the core; later, the opposite is true. In sum, the type of environmental changes, their frequency, and (implicitly) their magnitude have important consequences for how firms should allocate their attention. These implications can be deduced from the temporal dynamics of focused search reported in Figure 1.

Discussion

Organizations and their business models are often conceptualized as systems of interdependent choices that exhibit a core–periphery structure. Prior (theoretical and empirical) research is inconclusive,

Figure 5. Environmental Change and Focus



Notes. In this figure, we report the difference between focusing on core choices ($p = 2/3$) and focusing on peripheral choices ($p = 1/3$) for different points in time. Furthermore, we assume that every 20 periods there is an architectural change that turns core choices into peripheral choices and vice versa (gray dashed line), or a nonarchitectural change (solid black line). The vertical dashed lines indicate environmental shifts. In both cases, all performance contributions of the landscape are redrawn.

however, when it comes to the effect of focusing search efforts to core or peripheral aspects (e.g., Ethiraj and Levinthal 2004a). Using an NK simulation model, we sought to enhance our understanding of what may cause these inconsistencies. In our study, we focus on two types of factors that may contribute to these inconsistencies. First, there might be differences in how an organization's core is conceptualized. Second, the efficacy of searching core and peripheral choices might be influenced by unobserved moderators, specifically time horizon and environmental change.

We provide novel insights and predictions regarding both classes of explanations. It is important to note that our predictions are based on a model in which the dynamics of the coevolution of core and periphery emerge endogenously rather than being a priori assumptions. On an abstract level, we predict that all else being equal, a choice's influence (rather than its connectedness or dependence) is the main driver of the efficacy of search; furthermore, it is important to take into consideration whether a choice influences other influential or less influential choices. Together, these two aspects determine a system's key structural characteristics—hierarchy and decomposability. Our model predicts that the time horizon (and, by extension, the degree of environmental change) has important implications for the efficacy of search. Independent of the core–periphery relationship, a focus on core choices is always superior in the very short run; in the long run, however, differences in the efficacy of search only emerge if the system is not decomposable. In completely decomposable systems, a midterm liability of focus on core choices may emerge, whereas if there is a hierarchical relationship between the core and periphery, this problem may disappear. Our model also predicts, however, that in nearly hierarchical systems—that is, systems of mutual but asymmetric interdependence between core and periphery—this problem cannot always be alleviated. Taken together, these findings have important theoretical and empirical implications for several streams of research.

Core, Periphery, and Change

While it is broadly accepted that organizations can be productively viewed as systems of interdependent choices that exhibit a core–periphery structure, the implications of focusing search efforts on core choices are less well understood. For example, several reviews (e.g., Carroll and Hannan 2000, Siggelkow 2002, Ethiraj and Levinthal 2004a, Hsu and Hannan 2005) point to the inconclusive evidence regarding the impact of searching and changing core elements of an organization. In seeking to reconcile these inconsistencies, existing research has often adopted two broad strategies: refining the conceptualization of what constitutes an organization's core (e.g., Siggelkow 2002) and introducing moderator variables (e.g., Hannan and Freeman 1989, Greve 1999).

Refining the Conceptualization of the Core–Periphery Distinction. Related to the first strategy, prior work on search (Rivkin and Siggelkow 2007, Ghemawat and Levinthal 2008, Baumann and Siggelkow 2013) has demonstrated the directionality of connections among choices: does a choice depend on other choices or does it influence other choices? Directionality has important implications for both the structure of the performance landscape and the efficacy of search processes. We extend this argument and demonstrate that directionality also has important implications for the question of whether organizations should focus on core or peripheral choices and suggest that any conceptualization of the core–periphery distinction must take into account the directionality of connections. Broadly speaking, when coreness is defined as influence, it is beneficial to focus on core choices; however, when coreness is understood as dependence, focus on the core may hamper performance. Accordingly, we suggest replacing the notion of "coreness means connectedness" with "coreness means influence." Furthermore, in influencing other choices, it also matters whether the influenced choices are themselves more or less influential (i.e., what is the target of influence). If other influential choices are influenced, cascades of further changes may be required, rendering any change difficult. In contrast, if less influential choices are influenced, change cascades are less likely to emerge. Thus, we suggest that to fully understand the implications of searching core and peripheral choices, one must also take into account the target of influence.

Depending on the choices' direction and targets of influence, the system is more or less decomposable and more or less hierarchical. Hierarchy and decomposability, in turn, are key drivers for the efficacy of search (Simon 1962; Ethiraj and Levinthal 2004a, c). Interestingly, while prior research has emphasized the importance of near decomposability (Simon 2002, Fang and Ji-hyun 2018), research on hierarchy has not similarly examined the effects of different "degrees of hierarchy." This is all the more surprising given that most organizations in real-world contexts are only nearly hierarchical rather than fully hierarchical (see Rivkin and Siggelkow 2007 or Black et al. 1990 for examples). Our results suggest that a search focus in hierarchical systems leads to fundamentally different performance patterns than in near hierarchical systems.

Taken together, our arguments regarding the refinement of the core–periphery conceptualization have important implications for empirical research on the core–periphery distinction. Take, for example, the study by Siggelkow (2002) that identifies core choices by counting the number of connections of each choice and ranking them accordingly. Siggelkow (2002) also demonstrates that his method of identifying core choices is robust to alternative measures of centrality—that is, measures that, for example, may include farther-reaching connections such as the centrality measure of Bonacich (1987). Our findings suggest, however, that this robustness to alternative measures does not imply that the way core and periphery interact has no implications for the efficacy of focused search. For example, for long-run performance differences to emerge, the core and periphery cannot be decomposable subsystems. Standard measures of centrality may fail to pick up this important determinant of search efficacy and may therefore produce misleading results.

Moderator Variables. Inconsistent findings on the implications of a focused search may also have emerged because unobserved variables influenced the relationship between the search focus on core or periphery and the search performance. Starting with Hannan and Freeman (1984), variables such as organizational size, age, and complexity have been argued to moderate this relationship. In particular, our study emphasizes the important roles of time horizon and environmental change. For the time horizon, Hannan and Freeman (1984) speculate that the short-term effects of the change process are often detrimental even if the long-term effects arising from the content of the change may be beneficial. In their words, "Frequently, attempts to change core features to promote survival—even those that might eventually reduce the risk of failure by better aligning the organization with its environment—expose the organizations to a short run increased risk of failure" (Hannan and Freeman 1984, p. 160). A similar trade-off between short- and long-run performance has also been argued for many search mechanisms in the learning and adaptation literature. Search mechanisms that are superior in the long run are expected to come at some cost in the short and medium run, such as in the case of exploitation and exploration (March 1991, Levinthal 1997). While there are long-run advantages to being explorative (through global or more distant search), there are costs to exploration in the short run (see also Siggelkow and Levinthal 2003, Levinthal and Posen 2007, or Puranam et al. 2015 for other examples). Our study suggests that in the case of a search focus on the core or periphery, the temporal pattern might be much more complex—in some instances, a midterm liability may emerge for a focus on core choice, despite advantages in both the short and long run and is further depending upon the exact nature of the relationships within and between core and periphery.

In structural inertia theory, time is often treated as a proxy for environmental change—"age tracks the fit between an organization and its environment" (Hannan 1998, p. 158)—this increasing misfit is often discussed under the label of "liability of obsolescence" (Hannan and Freeman 1984). Our study points to an important dimension of environmental change that has been neglected in structural inertia models: the extent to which environmental change is architectural or nonarchitectural. With environmental change, some choices may no longer be the best fit to the changed environment. With architectural changes, there might be misfits not only in the choice level but also with the organization's focus of search. If there is no adaptation, the organization may find itself focusing on peripheral choices that were once core choices and vice versa. The implications for architectural and nonarchitectural environmental changes are fundamentally different and not taking into account this important dimension of environmental changes may result in confounding or even misleading empirical results.

Structural Inertia

Our study also speaks to research drawing on structural inertia theory. Since the work of Hannan and Freeman (1984), a line of research drawing mostly on population ecology (see, e.g., Carroll and Hannan 2000 for a review) has suggested that organizations find changes to the organization's core difficult, costly, and risky for the survival of the firm. This logic was adopted in the popular management literature of the 1990s and 2000s (e.g., Collins and Porras 1994, Zook and Allen 2010). The difficulty of changing core choices arises because these choices are often connected with the identity of the organization and lie at the heart of resource allocation processes, leading to deeply entrenched interests (Hannan and Freeman 1984). Furthermore, core changes may require subsequent adaptations of peripheral choices, thereby leading to a cascade of changes that may bind organizational resources and reduce the organization's ability to respond to opportunities in its environment (Hannan et al. 2003a, b). Because of these difficulties, costs and risks of core changes, organizations become increasingly inert.

We do not dispute the validity of this logic; however, structural inertia theory has simply *assumed* that core choices are difficult to change and that the short-term effects of the change process are always detrimental even if the long-term effects arising from the content of the change may be beneficial (Barnett and Carroll 1995) and core changes may provide important benefits that are difficult to achieve otherwise (Gulati and Puranam 2009). Our model considers both the process and content aspects of change. By integrating these two aspects, we can derive a much more nuanced understanding of the efficacy of search and change processes. Process and content do not evolve independently. For example, as illustrated in our experiments, if the level of adaptation is still very low (low-quality content), the adaptation (process) is substantially easier and still likely to be successful. As the organization becomes better adapted (high-quality content), the adaptation of core choices becomes increasingly difficult because changing core choices would likely lead to the maladaptation of those choices that are influenced by the core choice and, thus, the overall performance effect may become negative.

Furthermore, while structural inertia models *assume* that core choices trigger cascades of changes and that the change cascades increase the risk of organizational failure, these dynamics emerge endogenously from our model. The driving forces behind these cascades are the interdependencies among choices. The length of these cascades is a function of the exact nature of these interdependencies. Similarly, while structural inertia models *assume* that because core changes trigger cascades of changes, organizations are reluctant to change core elements and become inert, our experiments demonstrate such inertia can emerge endogenously from our model. In particular, if the organization is well adapted, changing core elements becomes increasingly difficult and unlikely to succeed.

Finally, high costs to searching and changing core elements (Hannan and Freeman 1984) have been invoked as an explanation for why organizations may refrain from focusing search on core elements. Consequently, if costs are low (because, for example, organizations can run low-cost experiments), a focus on core choices in the search process should become more attractive. Our results, however, demonstrate that even in the absence of high explicit costs to search and change (but instead, only implicit opportunity costs), a focus on core choices can be inferior to a focus on peripheral choices.

Business Model Innovation and Business Model Pivots

Our study also has important implications for the literature on the search for new business models. The topic of new business model search has received substantial interest in two related literatures. First, it is well established in the entrepreneurship literature (e.g., Gersick 1994, Nicholls-Nixon et al. 2000, Bhide 2003, Mullins and Komisar 2009) that new ventures must adapt and refine their business models, often involving substantial changes to their core, as they evolve from startups built around an idea to viable enterprises. This process has recently received renewed interest under the heading of "lean startups" (Ries 2011)—how new ventures can accomplish this task rapidly and at minimal cost. Under the heading of business model pivot (Garcia-Gutierrez and Martinez-Borreguero 2016, Levinthal and Contigiani 2018, Ries 2011), the lean startup literature proposes that frequent changes of core choices in a startup's business model are central to the process of searching and developing a viable business model. Second, the literature on business model innovation (e.g., Johnson 2010, Desyllas and Sako 2013, Spieth et al. 2014, Kim and Min 2015, Foss and Saebi 2017) suggests that changes to the core of the business model—for instance, changes in customers, changes in the value proposition, or changes to the operating model—may be central to innovating a firm's business model. Whereas both literatures provide substantial anecdotal and some empirical evidence for the potential benefits of such core changes to the business model (e.g., Chesbrough 2010, Girotra and Netessine 2014), a theoretical account of the underlying mechanisms continues to be largely absent (Foss and Saebi 2017).

Our arguments and findings make an important contribution to these streams of literature by refining their theoretical basis. The business model literature in particular has often conceptualized business models as complex systems of interdependent choices or activity systems (e.g., Casadesus-Masanell and Ricart 2010, Zott and Amit 2010). Casadesus-Masanell and Ricart (2010) also suggest that "some business models are decomposable" (p. 5). In other cases, such as Ryanair's business model (Casadesus-Masanell and Ricart 2010), the core and periphery are not decomposable but highly interconnected, and there are some asymmetries in the core–periphery relationship (i.e., their business model is nearly hierarchical). Other analyses of business models (e.g., Siggelkow 2002) ignore the direction of connections and thus, by definition, cannot detect any hierarchical relationships in the interaction between core and periphery. This is problematic because once there are asymmetries (or a hierarchy), the midterm implications for business pivots may be overturned completely. Our experiments point to the potentially disappointing results of business pivoting (i.e., core changes) for decomposable systems and nonhierarchical or nearly hierarchical systems, particularly in the midterm. In the midterm, business pivoting becomes less likely to be successful, despite the positive performance effects in the long run. These negative midterm effects are especially problematic because business models are often designed to be decomposable with the intention of allowing flexible changes to their core elements (Aversa et al. 2015). Our study suggests that it is not a system's decomposability but its hierarchical structure that makes business pivoting a successful strategy across all time horizons.

Interestingly, although they largely utilize the same conceptual building blocks, research on business model pivots and business model innovation is much more optimistic about core changes than the structural inertia perspective. Our arguments and simulation results suggest two important reasons for this divergence. First, structural inertia theory and business model innovation rely on different assumptions as to how organizations implement search and change: while the entrepreneurship and business model innovation literature highlights the importance of inexpensive experiments, structural inertia theory implicitly assumes that changes are always implemented organization-wide and are therefore costly. In the search literature, the former would be called offline and the latter online search (Lippman and McCall 1976, Gavetti and Levinthal 2000). With online search, even performance-decreasing changes might be implemented while offline search is strictly hill-climbing.[9] Second, while the entrepreneurship literature in particular focuses on less mature organizations, structural inertia theory focuses primarily on rather mature organizations. While we do not explicitly model maturity, our model includes several proxies of maturity. For example, mature organizations may differ from less mature organizations in the extent to which the system has become interdependent. Siggelkow (2002) describes this process as "thickening"—that is, the connections between core and peripheral elements become increasingly "thick." Depending on the directionality of these connections, this "thickening" process may result in hierarchical, nearly hierarchical, or nonhierarchical (but also nondecomposable) systems, with different implications for the efficacy of focused search. In Siggelkow (2002), thickening results in more dense connections between core and periphery—the influence of core choices on peripheral choices increases (and vice versa). With such increasingly strong coupling between core and peripheral choices, the focus on core choices may become a liability in the midterm (unlike in hierarchical systems).

In other words, whether organizations can benefit from a search focused on core choices depends on the relative strength of the potential benefits and the potential costs. For example, for young startup companies, the costs of experimentation and searching might be low. Indeed, in recent research on entrepreneurship and business model innovation, concepts such as "minimal viable product" (Ries 2011, Blank 2013), "experimenting" (Thomke 2003, Kaplan 2012), and "sandboxing" (Prahalad 2006, Ries 2011) emphasize the importance of quick and inexpensive experiments involving the core aspects of the organization. For many large, mature, integrated, and resource-intensive organizations,[10] such inexpensive experiments with core aspects of the business model are simply not possible. Thus, in more abstract terms, espousing the implicit assumption of these two bodies of literature also explains why the recent managerial literature on entrepreneurship and business model innovation is so much more optimistic about core changes than the older ecological perspective. The former body of literature emphasizes the importance of learning, updating, and adapting for young, less mature organizations, whereas the latter depicts more mature, established organizations as largely inert. One implication of our experiments may therefore be that more mature (or better adapted) organizations can benefit less from focusing on core choices than less mature (or less well adapted) organizations because of the rapidly increasing risk of searching core choices.

Designing Organizational Search Processes

Our arguments and results raise interesting questions for the design of organizational search processes (Puranam et al. 2012) and the relationship between an organization's organizational structure and structure of task interdependencies (Puranam 2018). According to the mirroring hypothesis (e.g., Conway 1968, Henderson and Clark 1990, von Hippel 1990, Chesbrough and Teece 1996, Sanchez and Mahoney 1996a, Baldwin and Clark 2000, Colfer and Baldwin 2016), it is often taken for granted that organizational structures (i.e., hierarchies of authority) correspond to the organizational task structuring. Given that research on organizational attention suggests that organizational structures shape the focus of attention, we may therefore expect that core choices may automatically become the focus of the search process. Yet, as highlighted by Puranam et al. (2012) and Puranam (2018), a mirroring between organizational and task structure cannot be taken for granted.

One implication of our results for the design of organizational search processes is therefore that organizations may utilize organizational design measures to shape focus in organizational search processes by creating mismatches between organizational and task structure. The attention-based view (Ocasio 1997, Bouquet and Birkinshaw 2008, Joseph and Ocasio 2012) therein points to the role of organizational structures in channeling and distributing attention within the organization. Put differently, channels such as strategic reviews, audits, committee meetings, and the CEO's office not only offer a key mechanism for processing information (e.g., March and Simon 1958, Henderson and Clark 1990) and transferring and integrating knowledge (Puranam and Srikanth 2007), but are also central in focusing the attention of organizational decision makers in organizational search (Ocasio 1997). By purposefully designing a mismatch between organizational structures and structures of task interdependence, organizations may improve the efficacy of organizational search processes by not only affecting whether organizations search and explore (Siggelkow and Levinthal 2003, Ethiraj and Levinthal 2004b, Fang et al. 2010, Levinthal and Workiewicz 2018, Puranam 2018), but also which organizational choices become the focus of attention in search processes. Most importantly, mismatches may result in a focus on peripheral choices, which in turn can be beneficial under some conditions.

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Endnotes

[1] Despite their different intellectual roots, the NK performance landscape model and structural inertia models share some commonalities. For more details, please see Hannan et al. (1996, p. 506) and Levinthal (1997) for discussions on how these models relate to each other.

[2] It is important to note that in the context of our study, hierarchy refers to the structures of interdependence among tasks and not the structures of influence among agents. For more details on these different hierarchies and their interplay, please see Puranam (2018).

[3] Decomposability is defined as the absence of interactions among subsystems (Simon 1962). In nearly decomposable systems, interactions among subsystems are weak but not negligible. Systems in which interactions among subsystems are asymmetric may become (more or less) hierarchical (Simon 1962, Ethiraj and Levinthal 2004a).

[4] Hannan and Freeman (1989, p. 84) call the interaction between (rather than the within) subsystems "(organizational) complexity... the patterns of links among subunits."

[5] The class of decomposable or nearly decomposable systems has received substantial attention under the heading of modularity (e.g. Baldwin and Clark 2000, Langlois 2002). In this paper, however, we utilize the original terminology as introduced by Simon (1962).

[6] In the interaction matrix, "influence" is reflected in column entries and implies that the value of other choices depends on this choice. Dependence, in contrast, is reflected in row entries. Dependence implies that the value of this choice depends on other choices.

[7] Indeed, absent any mechanism of nonlocal search or distant search, it is often assumed that all firms within the same basin of attraction

should converge to the same (local or global) peak, independent of how they focus their attention in the local search process. This, however, is a misconception, as highlighted already by Kauffman (1993).

[8] Such frequent changes are common in what Eisenhardt and colleagues (Bourgeois and Eisenhardt 1988, Eisenhardt and Bourgeois 1988, Eisenhardt 1989) refer to as "high-velocity environments." High-velocity environments are characterized by "rapid and discontinuous change in demand, competitors, technology and regulation." We discuss different types of changes in the robustness analysis in the online appendix.

[9] If search is offline, a focus on peripheral choices is always superior to a focus on core choices, regardless of the time horizon. Only in the extreme short run, there might be some benefits to a focus on core choices.

[10] This, however, does not imply that all mature and established organizations suffer from this problem. For example, Capital One conducts thousands of inexpensive experiments each year, varying interest rates, incentives, direct mail packaging, and other parameters for different groups of potential customers (Davenport 2009). In its letters to its shareholders, Sears highlights the strategic importance of the ability to run inexpensive experiments: "One of the great advantages of having approximately 2,300 large-format stores at Sears Holdings is that we can test concepts in a few stores before undertaking the risk and capital associated with rolling out the concept to a larger number of stores or to the entire chain."

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