

Journal of Management

<http://jom.sagepub.com/>

The Whole Is More Than the Sum of Its Parts— Or Is It? A Review of the Empirical Literature on Complementarities in Organizations

Edgar Ennen and Ansgar Richter
Journal of Management 2010 36: 207
DOI: 10.1177/0149206309350083

The online version of this article can be found at:
<http://jom.sagepub.com/content/36/1/207>

Published by:



<http://www.sagepublications.com>

On behalf of:



[Southern Management Association](#)

Additional services and information for *Journal of Management* can be found at:

Email Alerts: <http://jom.sagepub.com/cgi/alerts>

Subscriptions: <http://jom.sagepub.com/subscriptions>

Reprints: <http://www.sagepub.com/journalsReprints.nav>

Permissions: <http://www.sagepub.com/journalsPermissions.nav>

Citations: <http://jom.sagepub.com/content/36/1/207.refs.html>

The Whole Is More Than the Sum of Its Parts— Or Is It? A Review of the Empirical Literature on Complementarities in Organizations

Edgar Ennen
European Business School

Ansgar Richter
European Business School

The concept of complementarity denotes the beneficial interplay of the elements of a system where the presence of one element increases the value of others. However, the conceptual work on complementarities to date has not progressed sufficiently to constitute a theory that would offer specific predictions regarding the nature of the elements that form complementary relationships or the conditions for their emergence. To advance our understanding of complementarities, the authors provide a synoptic review of the empirical studies on this concept in leading journals in management, economics, and related disciplines over the period 1988-2008. The authors find that whether a study provides evidence of complementarities in organizations is at least partially driven by its investigative approach. On the basis of the findings, the authors argue that complementarities are most likely to materialize among multiple, heterogeneous factors in complex systems. Therefore, the absence of complementary relationships between a limited set of individual factors may not negate the possibility of complementarities, but rather point to the need for including further systems-specific factors in the analysis. The authors conclude by providing directions for future theoretical and empirical research and outlining managerial implications of the work.

Keywords: complementarities, organizational design

Acknowledgments: We thank John Roberts, Klaus Uhlenbruck, and the participants of the International Seminar on the Logic of Self-Reinforcing Processes in Organizations, Networks, and Markets in Berlin 2009 for their advice and Margaret Esselborn for her excellent assistance. A special thanks also to the Action Editor of the Journal of Management, Laura Poppo, and to several anonymous reviewers for their extensive and most helpful comments.

Corresponding author: Ansgar Richter, European Business School, Soehnleinstr. 8D, 65201 Wiesbaden, Germany

E-mail: ansgar.richter@ebs.edu

Journal of Management, Vol. 36 No. 1, January 2010 207-233

DOI: 10.1177/0149206309350083

© 2010 Southern Management Association. All rights reserved.

In recent years, the concept of complementarity and its role in the design of organizations has gained increasing attention (Porter & Siggelkow, 2008). In its most general form, complementarity exists when two activities reinforce each other in such a way that doing more of one thing increases the value of doing more of the other (Matsuyama, 1995). However, complementarities may also entail undesirable effects. For example, complementarities among the elements of tightly coupled systems may raise barriers to organizational change, as change in one element of the system would both require and effect change in many or all other elements of that system (Milgrom & Roberts, 1995b).

In this article, we provide a systematic review of the empirical literature in management and related disciplines on complementarities in organizations over the two decades after the contributions by Miller (1986), Teece (1986), and Milgrom and Roberts (e.g., Milgrom & Roberts, 1990a, 1990b) provided an impetus for many researchers to adopt the complementarity perspective in their work. Our work is motivated by the fact that this perspective is intriguing, yet it lacks the specificity about key constructs and causal relationships among them, which is a necessary condition for an approach to be considered a theory (Whetten, 1989). It offers little prediction regarding the conditions under which complementarities are likely to emerge or on the nature of the elements or factors (e.g., organizational characteristics) among which complementarities exist. By studying the empirical evidence, we aim to make inferences regarding the phenomenon of complementarity itself, and thereby lay the basis for future theoretical development.

Our review suggests that complementary relationships among heterogeneous factors in organizations may be powerful performance drivers. However, research that focuses on interactions between individual factors in isolation does not always detect these performance effects, as it disregards the role of contextual factors that may be constitutive for complementary relationships to materialize. We conclude that complementarities are systems-specific phenomena that result from the embeddedness of individual characteristics in the organizational nexus of relationships among multiple elements. However, this embeddedness poses significant challenges, both in terms of how to manage complementarities purposefully and in terms of how to account for it in empirical research. We sketch out avenues for further work in this area.

The Concept of Complementarity

The term *complementarity* is derived from the Latin word *complere*, “to fill up.” The notion of complementarity is used in many disciplines—it is most widely associated with the wave-particle duality in quantum physics (Englert, Scully, & Walther, 1991)—with varying meanings. Complementarity was introduced into economics by Edgeworth (1881). In economic terminology, complementarities exist when the mixed-partial derivatives of a payoff function are positive: Marginal returns from one variable increase in the level of the other variables (Milgrom & Roberts, 1994). The total economic value added by combining two or more complementary factors in a production system therefore exceeds the value that would be generated by applying these production factors in isolation.

In economics, the notion of complementarity has received tractability through the work of Stanford economists Paul Milgrom, John Roberts, and their coauthors. Drawing on the work of Topkis (1978, 1987), they use the mathematical study of supermodularity on lattices as an approach for formally modeling complementarities (e.g., Athey, Milgrom, & Roberts, 1998; Milgrom, Qian, & Roberts, 1991; Milgrom & Roberts, 1994). Supermodularity is the mathematical equivalent to the statement that “the gain from increasing every component . . . is more than the sum of gains from the separate individual increases” (Milgrom & Roberts, 1994: 5). Supermodularity can also be used to model situations in which changes in any one element may raise performance significantly only when combined with changes in many or all other elements (Milgrom & Roberts, 1994). This approach to modeling complementarities breaks with the assumptions of traditional economics in several important ways. First, classical economic models recognize only two fundamental production factors (capital and labor), thus emphasizing relative resource homogeneity (Ng, 2003). In contrast, the concept of complementarities relates to the idea that value creation results from combining many different resources, as already noted by Lachmann (1947). Second, traditional microeconomics assumes design choices to be infinitely divisible, the relationship between design choices (i.e., the objective function) to be concave, and the constraints set to be convex (Roberts, 2004). Under these assumptions, performance-optimal configurations can be identified through local experimentation: Decision makers adjust their systems in incremental steps and measure the resulting performance change until they have reached a point at which adjustments do not result in further performance improvements. In contrast, modeling complementarities in terms of supermodular functions on lattices can handle situations where combinations of design choices constitute a local, but not a global maximum, which may occur, for example, when the payoff function is discontinuous. If displayed on a performance landscape (Kauffman, 1993), different combinations of design choices can constitute multiple local “peaks,” without any need for a single “best” solution that trumps all others. Moreover, it highlights the fact that design choices, if they can even be adapted at will, often represent discrete rather than continuous variables that could be adjusted in increments. These insights have received further substantiation by authors applying the NK-model for simulating organizational designs (e.g., Levinthal, 1997; Levinthal & Warglien, 1999; Rivkin & Siggelkow, 2003).

In the field of strategy and organization, the notion of complementarity plays a role in several strands of literature. The term appears occasionally in publications throughout the 1960s and 1970s (e.g., Rothwell, 1975). It began to feature more prominently during the 1980s in the literature on organizational configurations (Miller, 1986; Miller & Friesen, 1984). In this approach, the term *complementarity* is used largely synonymously with *fit* and *congruence*. The central idea of this approach is that fit between contextual factors, strategy, and organizational structure would give firms a selection advantage over other organizations lacking such fit. Apart from survival, Miller (1986) and his coauthors (Miller & Friesen, 1984) did not make inferences about any performance effects of organizational fit.

A further approach that provided an impetus for later empirical research consists of Teece's (1986) discussion of the role of “complementary assets” in innovation. Drawing on transaction cost economic theory, Teece argued that the commercialization of an innovation may require additional complementary assets, in particular downstream capabilities such as marketing know-how, which are critical to a successful market introduction (Hill &

Rothaermel, 2003). If these assets are specific to the innovation concerned, the innovating firm may either have to maintain them in-house or otherwise accept that outside providers might extract a sizeable portion of the rents accruing from the innovation, due to their stronghold over the innovating firm.

Teece's (1986) idea that cospecialization among complementary resources within organizations may have beneficial effects also plays a role in the work of several authors (e.g., Powell & Dent-Micallef, 1997; Somaya, Williamson, & Zhang, 2007) who draw on the resource-based view (RBV) of the firm. The RBV also emphasizes the importance of resource heterogeneity, namely, the idea that firms derive competitive advantage from their ability to combine many different resources in unique ways (Adegbesan, 2009). However, while the approaches sketched previously are consistent with the idea that particular elements (resources, assets) may exert their (full) value only in the presence of other factors, they provide little clarity on the characteristics of the elements that may complement one another in general, namely, outside the particular context that they discuss.

Overall, the complementarity perspective does not constitute a theory, but a meso-level approach that helps researchers to understand relational phenomena as influencing and being influenced by forces on both the lower and the higher levels of analysis (Bies, Bartunek, Fort, & Zald, 2007; Hitt, Beamish, Jackson, & Mathieu, 2007). The notion of supermodularity enables economists to model, in a mathematically rigorous manner, the relationships among multiple organizational elements of complex systems as something more than the sum of these elements. Beneficial effects of such relationships are often coined *fit*, which has a rich intellectual tradition in macro-organizational theory (Drazin & Van de Ven, 1985). At the same time, the complementarity perspective does not provide predictions about the relationships among specific elements, as micro-level theories (e.g., in organizational behavior) typically do. Researchers may interpret interactions among individual factors as complementarities, but only *ex post*, as the complementarity perspective provides little guidance *ex ante* with respect to the nature of organizational design elements among which complementary relationships exist or the conditions under which they emerge. Moreover, if researchers do not find empirical evidence of individual interaction effects where they had expected them on the basis of the micro-level theories used, such a finding does not necessarily negate the possibility that complementarities may exist within the entire organizational system of which the two factors investigated are part. If they follow the alternative investigative approach—namely, to analyze the performance effects of entire systems containing multiple elements—they are faced with a similar problem: The complementarity perspective does not allow them to develop predictions *ex ante* about the exact configurations of the systems in whose performance effects they are interested. Moreover, the complementarity perspective does not specify the boundary conditions for the emergence of complementary effects. An important purpose of our review of the empirical literature is, therefore, to inductively generate insights on the nature of the organizational design elements that have been found to complement each other and the conditions under which such complementarities emerge.

Data and Method

Data Collection

Our review covers empirical papers published in six management-related disciplines, namely, strategy, organization and general management, economics, marketing, accounting and finance, information systems, and research and development (R&D) and innovation between 1988 and 2008. We focused on the top 80 academic journals by impact factor in the Social Sciences Citation Index (SSCI) 2007 ranking in these six subject areas. To balance comprehensiveness and manageability, we only took into account those studies explicitly using the notion of complementarity, searching the electronic library EBSCO for all papers in these journals that contain the word stem *complement*. This process yielded a total of 514 papers in management journals (36.8%), 599 papers in economics journals (42.8%), 70 papers in marketing journals (5.0%), 74 papers in R&D and innovation-related journals (5.3%), 81 papers in information systems journals (5.8%), and 60 papers in finance and accounting journals (4.3%), namely, 1,398 papers in all. These results indicate that the topic of complementarities has received most attention in management and economics and less in the other four areas. The journal with the largest number of publications containing the word stem *complement* is *Management Science* (85 papers), followed by the *Strategic Management Journal* with 82 publications. An analysis of the number of publications mentioning the notion of complementarities over time per discipline area suggests that interest in complementarity has grown, with a temporary peak in economics in the late 1990s, whereas, with 64 publications, interest in management reached a preliminary peak in 2008. Despite this increase as compared to previous years, it is clear that the notion of complementarity has not generated the “mass appeal” of some of the major theories in this area.

The fact that the five journals at the bottom of our list contained no further studies on complementarity suggests that our search has been fairly comprehensive. Nevertheless, we took two further steps to ensure our review would be as exhaustive as possible. First, we checked the reference lists of the papers that we decided to analyze more closely (see the following), which helped us to identify a further 9 papers that deal with complementarities, some implicitly without using the term in the abstract. Second, to avert the possibility of publication bias, we contacted the members of an established global network of academics in the field of organization theory via e-mail. We asked whether the recipients were aware of any studies on complementarities that have not been published (e.g., works in progress, unpublished doctoral theses, or papers that had not made it into academic journals) or that were published in outlets other than mainstream journals. The respondents drew our attention to 6 publications, which we also added to our list, leading to a total of 1,413.

As we had chosen a wide search parameter, it was clear that only a relatively small proportion of these papers consisted of empirical studies on complementarities per se, rather than to merely use the word stem *complement* without devoting much attention to this notion. Therefore, we analyzed the abstracts of the 1,413 papers, focusing on three search criteria. First, we selected only those papers that involved empirical research on complementarity. Our analysis revealed that about two-thirds of the studies on complementarities are of an exclusively conceptual nature. However, both the absolute and the relative number of empirical contributions appear to have grown over time.

Second, due to our focus on management issues, we disregarded a few papers on complementarities among chemical and biological substances in agricultural and environmental economics.

Third, we selected only those papers that addressed the complementary interplay among two or more factors (elements) in producing a particular outcome, however defined. This step led to the exclusion of some studies (e.g., White, 2000) that deal with “complementary assets” without, however, establishing any performance links. We excluded those publications that reported bivariate interaction effects without providing a reflection on the nature of the relationships between the constructs concerned from a complementarity perspective.

A total of 108 papers fulfilled all three criteria; these papers are the focus of our review that follows. We also draw additional insights from several simulation-based studies on complementarities (e.g., Rivkin, 2000; Siggelkow & Rivkin, 2005), although we did not include them among our empirical studies.

An analysis of the publication dates of the 108 studies suggests that more than two-thirds (70%) of these papers have been published in the last third of the 21-year period (1988-2008) we investigate, namely, between 2002 and 2008. Before 2002, publication activity in this area was limited to fewer than 5 papers per year. The earliest empirical study on complementarities in the literature that we review is the one by Miller (1988), who expressly integrated the notion of complementarities in his discussion of fit between firms’ market strategies, their organizational structures, and their market environment.

Approach

Many reviews of prior empirical work classify the studies taken into account by whether they address the antecedents of the phenomenon that they are interested in or its consequences. However, the notion of complementarities implies that it is impossible to identify “antecedents” that “lead to” complementarities yet are separable from them. Rather, if particular conditions or factors affect or interact with others in such a way as to produce a joint outcome that materially differs from the sum of the individual effects of these conditions treated separately, this relationship denotes the very essence of complementarity between the conditions (or “elements” or “factors”) concerned. Therefore, we decided to deviate from the standard review approach described earlier and analyze the empirical studies included in our review with respect to three major aspects.

First, we identified the *unit of analysis* of the paper concerned, namely, whether the paper relates to phenomena on the firm level (e.g., the interplay among organizational characteristics such as structural features, processes, or strategies), the individual level, the industry level, or any other level, including those studies that concern several units of analysis.

Second, to gain greater clarity regarding the nature of the elements among which complementarities can be expected to exist, we categorized the 108 studies by the *type of elements investigated*, using four different groups with two subgroups each (see Table 1). Our categorization draws on established concepts in the organization and strategy literature.

Resources. Our category *knowledge and capabilities* refers to human-bound competencies such as experience, knowledge, relationships, and intelligence (Barney, 1991). Resources such as technical or IT-related knowledge (e.g., Bendoly, Citurs, & Konsynski,

Table 1
Classification of Studies by the Type of Elements Investigated (in percent)

		Resources			Organization			Strategy			Environment		
		K	T	P	S	M	C	L	R				
Resources	K	28.7	12.0	2.8	5.6	1.9	7.4	1.9	1.9				
	T	12.0	8.3	5.6	6.5	1.9	1.9	0.9	–				
			46.3		15.7		12.0		4.6				
Organization	P	2.8	5.6	18.5	8.3	1.9	–	–	–				
	S	5.6	6.5	8.3	5.6	3.7	1.9	–	1.9				
			15.7		23.1		6.5		1.9				
Strategy	M	1.9	1.9	1.9	3.7	3.7	0.9	–	1.9				
	C	7.4	1.9	–	1.9	0.9	6.5	0.9	–				
			12.0		6.5		11.1		2.8				
Environment	L	1.9	0.9	–	–	–	0.9	–	–				
	R	1.9	–	–	1.9	1.9	–	–	0.9				
			4.6		1.9		2.8		0.9				
	Total per subcategory	53.7	25.9	30.6	25.9	11.1	16.7	3.7	5.6				
	Total per overall category	65.7		43.5		26.9		9.3					

Note: $N = 108$ studies (100%) Totals for each combination of cells are printed in bold figures. Totals do not represent sums of the individual cells, as studies involving elements from more than two categories are contained in several cells, but are counted only once in the respective Totals figure.

2007), internal R&D (e.g., Bin, 2008; Cassiman & Veugelers, 2006), and marketing capabilities (e.g., King, Slotegraaf, & Kesner, 2008) fall into this subcategory. Second, *technological assets* are nonhuman resources with physical qualities, such as information technology (e.g., Aral & Weill, 2007; Bertschek & Kaiser, 2004) or manufacturing technology (e.g., Colombo & Mosconi, 1995; Swink & Nair, 2006). A firm's resource endowments may include other types of resources such as its financial assets (Grant, 1991); however, the empirical literature on complementarities reviewed here relates only to elements that fall into the two subcategories identified earlier.

Organization. The empirical studies on complementarities address two aspects of the organization of firms, namely, its *practices and policies* and its *structure and processes*. The former category relates to what Simon (1945) called "organizational routines" and describes factors "that will determine with what skills, values, and knowledge the organization member undertakes his work" (Simon, 1945: 46), such as recruitment criteria (Cozzarin & Percival, 2006; Horgan & Mühla, 2006) or the promotion practices considered as fair (Macky & Boxall, 2007). We follow Child (1972: 2) in defining structure and processes as "the formal allocation of work roles and the administrative mechanisms to control and integrate work activities." Elements such as workplace organization (e.g., Bertschek & Kaiser, 2004; Black & Lynch, 2001) and degree of decentralization (Whittington, Pettigrew, Peck, Fenton, & Conyon, 1999) pertain to this subcategory.

Strategy. We apply the well-established distinction between *corporate strategy* and *market/competitive strategy*. Corporate strategy refers to all aspects of a firm's strategy that involve or apply to multiple business units or areas of operation, such as its diversification strategy (e.g., Tanriverdi, 2005) or cooperations, acquisitions, and alliances (e.g., Tiwana & Keil, 2007). Market/competitive strategy includes a firm's market focus (Cozzarin & Percival, 2006) and its choice of a cost leadership versus a differentiation strategy within a specific market (e.g., Chenhall & Langfield-Smith, 1998).

Environment. Only relatively few (9.3%) of the empirical studies on complementarities investigate relationships between organization-level characteristics and phenomena outside the organizations concerned. Among those that do, we were able to identify two subgroups: First, some studies (e.g., Roper, Du, & Love, 2008) take into account *location- or geography-specific* environmental factors. Second, a few studies address *regulatory or market conditions*, such as the degree of competition in an industry (e.g., Zott & Amit, 2008).

Third, we analyzed the 108 studies (and their findings) with regard to their *investigative approaches*, distinguishing between the *interaction approach* and the *systems approach*. The intellectual origins of this distinction go back to the early attempts to develop a general systems theory during the 1950s (see the contributions in the early editions of *General Systems*, the yearbook of the Society for General Systems Research, which was published for the first time in 1956). For example, Simon (1962) described complex organizational systems as (nearly) decomposable into subsystems in which a limited number of elements interact more directly with one another than they do with other elements of the system beyond the boundaries of the subsystem concerned. The distinction between approaches that investigate interaction

effects between individual elements and those that focus on the emergence of effects at the level of the entire system has permeated organizational theory this time. We draw on Drazin and Van de Ven's (1985) discussion of alternative forms of fit in contingency theory. Studies taking the interaction approach are those that analyze interaction effects between a limited number of clearly identified factors. Interaction-based studies are "reductionist" (Drazin & Van de Ven, 1985) in the sense that apart from what can be captured by a few control variables, they pay limited attention to contextual conditions that may influence the relationships among the variables investigated. At the same time, this focus allows studies taking the interaction approach to provide a relatively high degree of granularity and detail. The studies that take this approach may use, as independent variables, either categorical variables (describing whether a factor is in place or not) or, more commonly, rank-ordered or continuous measures of the relative or absolute level of the factor concerned. The main statistical method applied consists of regression analysis, where the relationships between the elements investigated are usually modeled as interaction effects. There is only one study in this category that is case based, namely, Brynjolfsson, Renshaw, and Van Alstyne (1997).

In contrast, studies that take a systems approach look at the relative performance outcomes of entire sets of multiple elements (Drazin & Van de Ven, 1985). Even in the qualitative studies within this category, individual elements (e.g., organization's decision-making structures, policies, and the like) are usually not described in great detail; rather, the focus is on the working of the entire system of factors. A distinguishing feature of these studies is their use of staggered analytical methods (e.g., Horgan & Mühlau, 2006; Ichniowski, Shaw, & Prennushi, 1997). In the first step, they use qualitative or quantitative (e.g., clustering) approaches to identify and describe systems as sets of multiple characteristics. This identification is based on whether a particular number, proportion, or combination of factors is in place. Therefore, if the studies in this category use measures for individual elements at all, these variables are typically of a categorical rather than a continuous nature (see Grandori & Furnari's, 2008, paper using Boolean comparative analysis). In the second step, they analyze the relationship between the extent to which organizations conform to the identified systems and their performance, using a variety of techniques (e.g., likelihood ratio tests, as is the case in Belderbos, Carree, & Lokshin, 2006). The distinction between the interaction approach and the systems approach allowed us to classify all of the 108 studies in an unequivocal way, with 47 studies belonging to the former group and 61 studies to the latter.

Results

Unit of Analysis

Our review reveals that well over 90% of the 108 studies use the *organization*, namely, the *firm*, as the primary unit of analysis. With the exception of Carmeli and Tishler's (2004) investigation of Israeli local authorities, we did not find any studies on complementarities in not-for-profit organizations; hence, we use the terms *firm* and *organization* interchangeably. There are some studies that deal with complementarities among different types of knowledge, skills, and capabilities on the individual level (Bonaccorsi & Thoma, 2007; Mithas & Krishnan, 2008). Only a few studies use the industry as their unit of analysis (e.g., Bin, 2008; Shane, 2001).

Of the studies that use the firm as the unit of analysis, the clear majority focus on within-firm characteristics, for example, on the beneficial interplay among a set of human resources (HR) practices within an organization (Ichniowski et al., 1997) or on complementarities between a firm's technological assets and its capabilities (Ravichandran & Lertwongsatien, 2005). There are some studies that investigate the role of complementarities between firms (e.g., Arora & Gambardella, 1990; Cassiman & Veugelers, 2006); however, even in these studies the focal point of interest—as evidenced by their choice of dependent variable—is on firm performance. The use of the organization as the main unit of analysis differs markedly from other studies in management, in which units of analysis other than the organization account for about 50% to 60% of all studies (Kirkman & Law, 2005). Overall, our analysis suggests that the empirical literature reviewed here conceives the notion of complementarities primarily as an organization-level phenomenon.

We also noticed that almost all of the studies reviewed here take a cross-sectional perspective on complementarities, using static measures of performance (e.g., productivity) or performance changes over relatively short periods of time (as in the case of Forman, 2005, and Tanriverdi & Lee, 2008) as their dependent variables. We found only six studies (Benner & Veloso, 2008; Brynjolfsson & Hitt, 2003; Rothaermel and Hill, 2005; Ruiz-Navarro, 1998; Siggelkow, 2001; Toole, 2007) that employ a truly longitudinal perspective. Except for the papers by Brynjolfsson and Hitt (2003) and Siggelkow (2001), the literature reviewed here provides little evidence on organizational change and transformation or on the coevolution of firms and their environments.

Types of Elements Investigated

Table 1 provides the results of our classification of the 108 studies included in our data set by the types of elements among which the studies were searching for complementary relationships. Table 1 also shows that the empirical research on complementarities has paid most attention to the relationships among particular resources, namely, to the relationships between the resources of an organization and its organizational design, strategy, and/or environment. In total, 71 (65.7%) of the 108 studies reviewed included resources among the factors with respect to which the authors investigated potential complementary relationships. Within the resource category, by far the largest group of studies has looked specifically at the role of knowledge and capabilities (as compared to technological assets) as potential constituents of complementary relationships. Of these studies, the clear majority find that the careful matching of knowledge resources or capabilities with other types of such resources or with other factors, such as a firm's strategy, generates beneficial outcomes above and beyond the effects of these factors on their own. For example, Christman (2000) analyzed the relationship between process innovation and implementation capabilities, the use of pollution prevention technologies, and the timing of environmental strategies among chemical firms, finding that these resources reinforce the benefits of early strategy adoption and vice versa.

Another group of elements that has received significant attention in the empirical literature relates to aspects of firms' organization. In total, 47 (43.5%) of the 108 studies include at least one organizational element among the factors with respect to which complementary

relationships are being investigated. Within this category, about equal attention has been paid to the role of policies and practices as to structures and processes.

In comparison, we found substantially fewer studies (29 in total, representing just 26.9% of the 108 papers) that include strategic factors among the elements among which complementary relationships are being investigated. In particular, with just 12 studies (11.1%), any potential complementarities between firms' market strategies and other elements have rarely been analyzed. Aspects of a firm's corporate strategy were slightly more often included in the 108 empirical papers in our database, as in the case of Rothaermel and Hess's (2007) study of complementarities between the biotechnology alliance and acquisition strategies of global pharmaceutical companies and their resources (human capital, R&D capabilities). We found only 1 study (Siggelkow, 2001) that investigates complementary relationships between a firm's corporate and its market-facing strategies. There are also relatively few papers (7, representing 6.5% of the total) that analyze complementary relationships between aspects of a firm's strategy and its organization's structures or practices. Against the background of the long-standing debate about fit between "strategy and structure" (Chandler, 1962), this result was surprising for us.

Finally, few studies (10 out of 108) address complementary relationships between a firm's environment and other factors, such as its resources, organization, or strategy, although Song, Droge, Hanvanich, and Calantone (2005) showed that environmental conditions (e.g., technological turbulence) may play an important role as facilitators or constraints in the emergence of complementarities. We were, again, surprised by this finding, given that contingency-theoretic approaches have long seen performance as deriving from the optimal alignment between organizational design variables and environmental conditions (Miller & Friesen, 1984). The methodological difficulties involved in multilevel studies (Hitt et al., 2007) might account to some extent for the relative scarcity of studies involving environmental factors.

Findings of the Studies Reviewed

To obtain an overview of the findings of the 108 studies in our review, we classified them by whether they found evidence of a complementary or substitutive relationship, or no relationship, between the factors investigated (see Tables 2 and 3). We categorized a study as finding complementary effects between two or more factors when it provided evidence of positive effects above and beyond the individual effects of these factors on beneficial outcomes such as performance.¹ In studies taking a quantitative approach, these effects had to be statistically significant at conventional levels. When a study found that the presence of a factor diminished the effect of another factor on desirable outcomes, we classified this study as one finding a substitution effect between the two factors concerned. Finally, we recorded studies that found neither a complementarity nor a substitution effect between two or more factors.

Our analysis reveals marked differences in the findings between the studies taking the interaction approach and those adopting the systems approach.

A broad comparison between Tables 2 and 3 suggests that the 47 studies taking the interaction approach provide more mixed results with respect to any potential complementary relationships among the elements investigated than the 61 papers using the systems approach.

Table 2
Overview of the 47 Studies Applying the Interaction Approach

		Resources			Organization			Strategy			Environment		
		K			T			P			S		
		+	0	-	+	0	-	+	0	-	+	0	-
Resources	K Knowledge, capabilities	16 21 31 50 67 68 92 94 99	31 66 68	31 80 86									
	T Technology	02 55 59 70 107	02 47 59	59 40 55									
Organization	P Policies, practices	06 21 96	06 96	09 70 05				09 14 19 27 20 38 27 38 72 105	15 19 15				
	S Structures, processes	08 12 21 22		22 70 89 89				14 15 15 38	15 14 38				
Strategy	M Market strategy			70 70 70				34 34	108 108	13			
	C Corporate strategy	24 46 50 80 83 89 95	46 50 83	80 44 44 90						44 91			
Environment	L Location, geography			40									
	R Regulations, market conditions							35	13 13				

Note: Numbers contained in the cells denote individual studies (indicated by uppercase numbers in the reference list). Any study may be contained in more than one cell, depending on the type of element investigated, and the findings of the study. + = Study finds complementary effects between elements contained in the respective categories. 0 = Study finds no or no statistically significant complementary or substitutive effect between elements contained in the respective categories. – = Study finds substitutive effects between elements contained in the respective categories.

Table 3
Overview of the 61 Studies Applying the Systems Approach

		Resources						Organization						Strategy						Environment					
		K			T			P			S			M			C			L			R		
		+	0	–	+	0	–	+	0	–	+	0	–	+	0	–	+	0	–	+	0	–	+	0	–
Resources	K Knowledge, capabilities	03 10 29 32 36 42 56 57 60 65 69 79 81 82 87 98 101 106	32 48 87 98																						
	T Technology	17 49 73 74 75 82	84		23 33 41 54 100	73 73																			
Organization	P Policies, practices				11 49 73			01 30 37 39 45 51 52 53 58 102	45 62																
	S Structures, processes	42 71			11 17 18	49		52 53 58 61 63 103			52 74 103														
Strategy	M Market strategy	28 76			28			25			25 26 64	26		28 29 76											
	C Corporate strategy	93									85 103			85			04 07 43 77 78	07							
Environment	L Location, geography	76 104	76 104														04								
	R Regulations, market conditions	42 87									64			97									42		

Note: Numbers contained in the cells denote individual studies (indicated by uppercase numbers in the reference list). Any study may be contained in more than one cell, depending on the type of element investigated, and the findings of the study. + = Study finds complementary effects between elements contained in the respective categories. 0 = Study finds no or no statistically significant complementary or substitutive effects between elements contained in the respective categories. – = Study finds substitutive effects between elements contained in the respective categories.

Specifically, among the studies taking the interaction approach, only 18 (38.3%) of the 47 studies find complementary relationships among all the elements they investigate. In all, 25 studies (53.2%) find evidence of complementary relationships between some elements but substitution effects or no effects between others. The remaining 4 papers (8.5%) find, against their expectations, no complementary relationships among any of the factors studied.

In contrast, of the 61 studies taking the systems approach, 47 (77.0%) find unequivocally positive evidence of complementarities among all of the factors considered. Only 3 studies in this group, namely, Hill and Hellriegel (1994), Schultze and Orlikowski (2004), and Macky and Boxall (2007), did not find any evidence of complementarities at all (neither did they find substitution effects). Overall, these results suggest that the likelihood that a study finds evidence of complementary effects is at least partly driven by its underlying investigative approach.

A closer analysis of the studies taking the interaction approach is particularly instructive with respect to the nature of the elements among which complementary effects are likely, or less likely, to emerge. In contrast, the papers adopting the systems approach provide insights on the performance effects of entire configurations of multiple elements. We discuss both aspects in the following, beginning with the former group of studies.

Studies taking the interaction approach. We highlight four results emerging from the analysis of the 47 papers in this group. First, the evidence suggests that the combination of factors in a particular category (e.g., our resources category; more than 70% of the 47 studies in Table 2 involve at least one element of an organization's resource usage) with elements in other categories (e.g., the organization or strategy categories) constitutes a source of at least some complementarities among the elements concerned. Of the 4 papers contained in Table 2 that do not provide evidence of any complementarities, 3 investigate the relationships between particular resources and other resources (Helfat, 1997; Mithas & Krishnan, 2008; Somaya et al., 2007). Only 1 paper (Athey & Stern, 2002) that relates a particular type of resource (e.g., IT systems) to a set of organizational policies and practices (e.g., skill-oriented job design) provides no evidence supporting a complementary relationship between these factors (neither does it find a substitutive relationship). Overall, this evidence suggests that while combining resources of a particular type with other resources of a similar type within the same firm may yield complementary effects, it is not a reliable source of complementarities. Complementarities in social systems appear to result from the interplay among heterogeneous factors, such as resources, organizational structures and strategies, and/or others.

Second, inspection of Table 2 suggests that only 8 of the 21 studies involving at least one element of organizational policies/practices or structures/processes find universally positive complementary effects between the organizational element(s) considered and other elements (Bendoly et al., 2007; Carmeli & Tishler, 2004; Cremers & Nair, 2005). The other 13 studies involving at least one organizational element provide mixed results; namely, they find substitution effects or no effects in addition to any complementary effects among the factors considered. Therefore, the use of organizational practices or structures per se does not appear to result in complementary effects; rather, whether complementarities emerge depends on the specific practices and structures in place and their combination with other factors. A case-by-case analysis of the 21 papers involving organizational factors shows that around one-third

of these investigated relationships among individual workplace and other HR-related practices, such as job rotation, training, incentive schemes, and/or profit-sharing programs, and decentralized decision making. Their general finding is that one-on-one relationships between individual practices are often not complementary, but rather additive (e.g., Black & Lynch, 2001; Bocquet, Brossard, & Sabatier, 2007; Capelli & Neumark, 2001; Delaney & Huselid, 1996). We will come back to this finding and compare it with the results of studies in the same topic area taking the systems approach in the following.

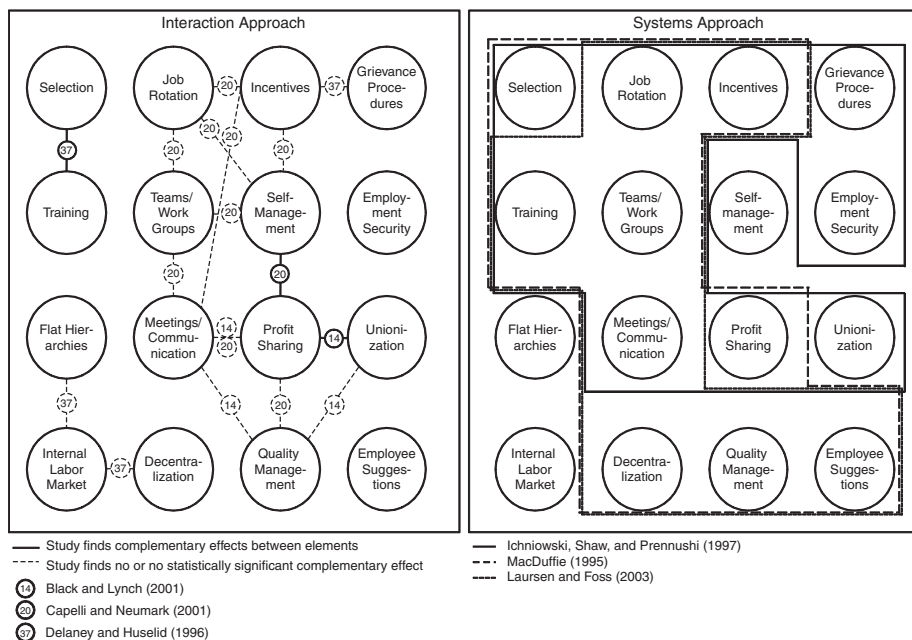
Third, Table 2 shows that 14 studies on relationships between individual aspects of a firm's market or corporate strategy and other factors are available. Of particular prominence in this group are 4 studies on different types of strategic relatedness (e.g., product market relatedness, customer knowledge relatedness) in multibusiness firms by Tanriverdi and his coauthors (Tanriverdi, 2005; 2006; Tanriverdi & Lee, 2008; Tanriverdi & Venkatraman, 2005). All 4 of these studies attest to the idea that these different types of relatedness enhance each other's marginal effects on aggregate firm-level performance outcomes, at least for moderate levels of diversification. This evidence suggests that a firm's pursuit of relatedness strategies may have a twofold benefit, namely, through their individual effects on performance on the one hand and through complementary effects with the firm's resources, organization, or other aspects of its strategy on the other.

Fourth, only 3 of the 47 studies using the interaction approach take aspects of an organization's environment into account in their analysis of complementary relationships. It appears that the highly granular perspective characteristic of the interaction approach may divert the attention of researchers from the potential importance of the wider environmental conditions that may themselves be constitutive elements of complementary relationships.

Studies taking the systems approach. As indicated earlier, the research pursuing the systems approach yields largely positive findings regarding the existence of complementary relationships among entire systems of multiple elements. Inspection of Table 3 shows that more than three-quarters of the papers taking this approach (47 of the 61 studies) provide evidence of entirely positive complementary effects, and a further 11 papers find some complementary effects where they had expected them, in addition to some substitutive or insignificant effects. Only the 3 remaining papers (Macky & Boxall, 2007; Hill & Hellriegel, 1994; Schultze & Orlikowski, 2004) show no significant results that would attest to the existence of complementarities, but even these papers do not negate the possibility of complementarities on the systems level (i.e., there are no studies in this group that would find only substitutive effects where complementary effects had been expected). In particular, the 23 studies that include organizational elements (organizational policies/practices and/or structures/processes) in the analysis of systems considered come to virtually unalloyed positive conclusions regarding the existence of complementary effects in the systems concerned.

We use the example of the HR management (HRM) literature to illustrate the difference between the studies using the systems approach and those taking the interaction approach. All of the studies in this area using the systems approach confirm that the combination of multiple elements of "modern" HRM positively affects aggregate firm performance. In contrast, the findings on one-on-one relationships among individual HR practices cast a more skeptical light on this issue. Figure 1 presents a graphic comparison between three studies

Figure 1
Comparison of Elements Combination Between the Two Investigated Approaches



using the interaction approach (Black & Lynch, 2001; Capelli & Neumark, 2001; Delaney & Huselid, 1996) and three papers using the systems perspective (Ichniowski et al., 1997; Laursen & Foss, 2003; MacDuffie, 1995).

While each of the six studies involves only a subset of the 16 elements depicted in Figure 1, both groups of studies discuss largely the same type of elements. The three papers in the interaction approach category each investigate between 4 (Black & Lynch, 2001; Delaney & Huselid, 1996) and 10 (Capelli & Neumark, 2001) one-on-one relationships. Each study finds only one of the relationships to be of a complementary nature; all other relationships were found to be substitutive or insignificant. In contrast, the studies using the systems perspective include between 8 (Laursen & Foss, 2003) and 10 (Ichniowski et al., 1997; MacDuffie, 1995) factors in describing and identifying whether bundles of HRM-related practices were present in the organizations contained in their samples. While the choice of the factors varies somewhat from study to study, five factors (training, incentives, job rotation, teams/work groups, meetings/formal means of communication) are contained in each of the three papers. These five factors are also studied heavily in the three papers using the interaction approach. As Figure 1 shows, the studies taking the systems approach find evidence supporting the idea that organizations that use these HRM-related practices outperform organizations that do not use them or only a limited range of them.

Further insights derive from an in-depth analysis of the 14 papers in the systems approach category that provide mixed or insignificant results regarding the existence of complementary relationships. We found that 6 of these 14 papers analyze potential complementarities among firm characteristics, such as resource endowments, in interfirm relationships, usually in the context of alliances or vertical (supplier-buyer) relationships. For example, Colombo, Grilli, and Piva (2006) investigated whether the combination of different specialized resources such as commercial and technological assets by young technology firms yields beneficial outcomes, finding some positive and some insignificant effects. In contrast, the clear majority of the systems-based studies yielding unequivocally positive findings on the existence of complementarities look at the relationships of elements within organizations. This finding that complementarities are more likely to materialize within rather than between organizations has implications for the question of where researchers should draw the boundaries of organizational systems.

Discussion

Summary of Main Findings and Theoretical Implications

Our review of the empirical literature on complementarities in this article was motivated by the recognition that the complementarity perspective does not provide much specificity with respect to the nature of the factors among which complementarities can be expected to exist, nor does it provide predictions regarding the conditions facilitating the emergence of complementarities. Therefore, in its current state of conceptual development, the complementarity perspective allows identifying complementarities only *ex post*, on the basis of their performance effects (Athey & Stern, 1998).

Overall, our review of the 108 studies analyzed in this article suggests that complementarities among organizational design elements *may* constitute powerful performance drivers. Of these studies, 101 find evidence of at least some complementarities; only the 7 remaining studies could not confirm the existence of any complementarities where they had expected them. However, a closer look at the results indicates that one-third (36) of the 108 studies provides mixed evidence on complementarities. Furthermore, our review of the 47 studies taking the interaction approach did not provide evidence of a “magic bullet”: We did not find a single factor in these studies whose co-occurrence with other factors would invariably result in the emergence of complementary relationships. In the same vein, we did not find evidence of a “magic pair of bullets,” namely, a pair of factors whose relationship would always be complementary, regardless of content.

We find that the studies taking the systems approach provide substantially more positive results on complementarities than those taking the interaction approach. For example, whereas 77% of the studies taking the systems approach come to entirely positive conclusions regarding the existence of complementarities, the same is true only for 38% of the papers taking the interaction approach. We are particularly intrigued by our finding that even studies looking at the same topic area (as exemplified by the studies on HRM practices) may come to fairly different conclusions regarding the existence of complementarities, depending on their choice of investigative approach. Overall, the likelihood that a study produces positive or less positive findings regarding the existence of complementary effects appears to be at least partially driven by this choice.

Therefore, our comparison suggests that complementarities are most likely to materialize in a system of complex interactions among multiple elements. The analysis of one-on-one relationships among individual factors produces insightful results; however, if a study fails to detect a complementary relationship between two factors where one was expected, this result may well be due to the role of other elements not considered in the analysis. As Matsuyama (1995) noted, two factors are not complements by virtue of their own nature, but by virtue of the presence of what he called a “third alternative,” namely, a third factor that may or may not be in place. For example, Bocquet et al. (2007) argued that particular organizational practices and strategic choices complement each other only when geared toward a particular set of information and communication technologies (ICTs), and that other ICT configurations require different “bundles” of organizational practices and strategies. Similarly, Cassiman and Veugelers (2006) argued that success in innovation requires not only combining the “right” innovation practices, but also creating an organizational context in which these practices enhance each other in an optimal fashion. Two factors may complement one another, yet the description of these two factors and their interaction does not constitute an exhaustive analysis of the conditions under which this complementarity holds. To put it more pointedly, two factors *are* not complements; they *become* complements by virtue of a third factor (or set of factors). Complementarities may only become fully effective when embedded in an overall system involving many elements. Therefore, a theory of complementarities will have to take the critical role of contextuality into account. Establishing entire systems of mutually reinforcing design elements leads not only to enhanced performance, but has additional benefits in that complex systems provide protection against imitation by competitors (Rivkin, 2000).

The insight that complementary relationships among specific factors may emerge only in the presence of further factors is also consistent with our finding that complementarities benefit from *heterogeneity*. As the example of the three papers on HRM practices that use the interaction approach (Black & Lynch, 2001; Capelli & Neumark, 2001; Delaney & Huselid, 1996) shows, combining several HRM practices—factors that are relatively similar to one another in that they belong to the same category, namely, organizational practices (see Table 2)—may well produce additive rather than complementary effects. Furthermore, we find that three of the four papers taking the interaction approach that provide evidence of no complementarities at all where they had expected them related firms’ resources of a particular type with other types of resources without considering the potential importance of organizational policies, structures, strategies, or environmental conditions. Furthermore, many of the studies investigating the combination of relatively similar factors find substitution effects among them. For example, Nerkar and Roberts (2004) provided evidence according to which an organization’s experience in different fields such as marketing and technology enhances innovation performance, whereas resources in similar fields (e.g., proximal and distal technological experience) cannibalize each other with respect to new product success. Conversely, Bonaccorsi and Thoma (2007) showed that the cooperation between different types of inventors is more effective than the cooperation among inventors with similar skill sets.

Overall, we interpret these findings as indications that the added value that complementarities provide above and beyond the value of each individual factor may result from the combination

of multiple, heterogeneous factors. Along the same lines, Grandori and Furnari (2008) proposed the “law of structural heterogeneity,” according to which the effective design of systems results from the combination of organizational attributes of different kinds, rather than of attributes of the same kind.

To summarize, our review provides two interrelated insights that, from our point of view, should be the basis for further theory development: First, we find that complementarities emerge in complex systems involving *multiple* elements. Second, these elements involved in the emergence of complementary relationships are of a *heterogeneous* nature. As the recent work by Adegbesan (2009) showed, these insights can be utilized to explain persistent performance differences between seemingly similar firms (e.g., firms active in the same factor and product markets), without resorting to superior expectations (e.g., regarding the value of specific resources) or luck. He argued that these performance differentials may result from differences in the abilities of firms to generate complementarities among seemingly different things (resources, organizational practices, strategies, etc.). Therefore, competitive advantage may not (or not only) result from firms’ ability to attract resources, but also from the ability of firms to integrate them in a unique way that enhances the overall value of the organizational system. In line with Adegbesan’s work, we believe that the notion of complementarity has the potential to become the cornerstone of a theory of organizational performance. Further work is needed to develop such a theory.

Directions for Future Empirical Research

Our review has shown that a good deal of progress has been made with respect to investigating the role of complementarities in organizations from an empirical point of view. As indicated earlier, the findings of the 108 studies analyzed here are relatively encouraging, with the studies supporting the existence of complementarities clearly outnumbering the papers finding no or negative results. At the same time, we have found significant differences between the studies depending on their investigative approaches. From our point of view, further empirical research should avoid walking the beaten tracks of the interaction approach versus the systems approach and seek to explore the middle ground between them. Research primarily interested in the relationships among individual factors should pay greater attention to the importance of contextual factors, both within the organization and in its wider environment (see the following). On the other hand, analyses that focus on entire systems of factors should provide greater specificity with respect to the relationships among the features of the system concerned. Many papers using quantitative approaches attempt to capture the nature of distinct organizational systems by using categorical variables indicating whether particular factors are in place or not. This approach provides little information on the nature of the relationships that ultimately drive complementarity effects observed at the systems level. One study that occupies this middle ground is Siggelkow’s (2001) qualitative paper on change in the presence of fit at Liz Claiborne, which provides ample detail on how

individual factors (e.g., choices on product range, production and distribution methods, marketing methods) relate to one another, without losing sight of the overall organizational configuration of the firm concerned at two different points in time. Further empirical research should follow this example.

Furthermore, we were surprised about the paucity of studies—even of those adopting the systems approach—that would take the environment into account in examining potential complementarities. It appears that a central tenet of configuration and contingency theories that see the choice of organization-specific factors such as strategies and structures has been left largely unexplored from a complementarity perspective. There are many examples (e.g., Milgrom & Roberts's, 1994, discussion of the organization of Japanese firms) that indicate that tightly coupled organizational designs may be successful under certain environmental conditions but less successful under others. We agree with Porter and Siggelkow's (2008) argument that researchers aiming to trace complementarities in organizations need to take greater account of contextual factors in their studies, including the industry context, but also social, political, and other dimensions of the environment in which firms operate.

Finally, our review shows that most empirical studies on complementarities assume a cross-sectional perspective and that they largely use performance measures of various types. Given that the notion of complementarities has a potentially major application in explaining organizational stability and inertia and the emergence of recurring design patterns within and across organizations, we would hope that future research pays greater attention to outcomes such as longevity, survival, and organizational resistance or ability to cope with change. Such research is likely to require longitudinal data and possibly to involve qualitative research approaches in addition to quantitative ones.

Implications for Managerial Practice

The complementarity perspective is skeptical of the notion of “best practices,” which supposedly enhance performance regardless of the circumstances in which they are applied. It suggests that decision makers have to manage complex social systems whose constituents and interactions are usually incompletely understood and whose benefits may only become apparent post hoc. Furthermore, the success of organizations that have established tightly coupled systems among highly complementary elements may act as a strong barrier to change, and thereby hinder adaptation and survival (Roberts, 2004).

Nevertheless, we highlight two implications for managerial practice that can be derived from the empirical research reviewed in this paper. First, although the evidence on complementarities is not clear-cut, this evidence is by no means negative. In total, 65 of the 108 papers contained in our review have found only positive performance effects of the relationships between individual factors or among multiple elements of the systems they considered. A further 36 studies found mixed evidence. Therefore, complementarities, although clearly not ubiquitous, appear to be widespread, suggesting that the development of organizational systems embodying such complementarities is achievable at least in principle. Although due to the large differences in the data, variables, and methodologies used by the papers in our

review, it is impossible to assess the performance effect sizes of complementarities in a statistical sense, and analysis of individual studies (e.g., Carmeli & Tishler, 2004) suggests that these effects can be substantial. Organizational development toward complementarities holds out a promising perspective.

Second, although our review has not enabled us to pinpoint individual factors that provide “universal complementarity” with other factors, it has provided a snapshot of the various dimensions that decision makers seeking to facilitate the emergence of complementarities in their organizations should take into consideration. Managers should take a broad view of their organizations that cuts across the boundaries of traditional functional demarcations. As Milgrom and Roberts’s (1990a) example of Ford shows, a firm’s human resource management is most likely to exert its full benefit in consort with its strategy, organizational structures, and other characteristics. The complementarity perspective suggests that lasting competitive advantage does not necessarily derive from optimizing each of these factors on its own, but from the beneficial interplay among them.

Note

1. The studies that take the industry as their main unit of analysis are not included in our count of 108 papers and are not listed in Tables 1 through 4 as it was not possible to form an evaluative assessment of the outcome variable used in these studies. For example, Shane (2001) used the rate of new firm entries into an industry as his dependent variable. Whereas public policy makers might consider the emergence of new firms as desirable, industry incumbents may not welcome competition from new companies.

References

The 108 studies included in our review of the empirical studies on complementarities are identified by a superscript number (used in Tables 2 and 3).

- Adegbesan, J. 2009. On the origins of competitive advantage: Strategic factor markets and heterogeneous resource complementarity. *Academy of Management Review*, 34: 463-475.
- ¹Aguilera, R. V., Filatotchev, I., Gospel, H., & Jackson, G. 2008. An organizational approach to comparative corporate governance: Costs, contingencies, and complementarities. *Organization Science*, 19: 475-492.
- ²Aral, S., & Weill, P. 2007. IT assets, organizational capabilities, and firm performance: How resource allocations and organizational differences explain performance variation. *Organization Science*, 18: 763-780.
- ³Arora, A., & Ceccagnoli, M. 2006. Patent protection, complementary assets, and firms’ incentives for technology licensing. *Management Science*, 52: 293-308.
- ⁴Arora, A., & Gambardella, A. 1990. Complementarity and external linkages: The strategies of the large firms in biotechnology. *Journal of Industrial Economics*, 38: 361-379.
- Athey, S., Milgrom, P., & Roberts, J. 1998. *Robust comparative statics*. Unpublished manuscript, Stanford University.
- Athey, S., & Stern, S. 1998. *An empirical framework for testing theories about complementarity in organizational design*. NBER Working Paper No. 6600, Cambridge, MA.
- ⁵Athey, S., & Stern, S. 2002. The impact of information technology on emergency health care outcomes. *RAND Journal of Economics*, 33: 399-432.
- ⁶Baer, M., & Frese, M. 2003. Innovation is not enough: Climates for initiative and psychological safety, process innovations, and firm performance. *Journal of Organizational Behavior*, 24: 45-68.

- Barney, J. 1991. Firm resources and sustained competitive advantage. *Journal of Management*, 17: 99-120.
- ⁷Belderbos, R., Carree, M., & Lokshin, B. 2006. Complementarity in R&D cooperation strategies. *Review of Industrial Organization*, 28: 401-426.
- ⁸Bendoly, E., Citurs, A., & Konsynski, B. 2007. Internal infrastructural impacts on RFID perceptions and commitment: Knowledge, operational procedures, and information-processing standards. *Decision Sciences*, 38: 423-449.
- ⁹Benner, M. J., & Veloso, F. M. 2008. ISO 9000 practices and financial performance: A technology coherence perspective. *Journal of Operations Management*, 26: 611-629.
- ¹⁰Beresteanu, A. 2005. Nonparametric analysis of cost complementarities in the telecommunications industry. *RAND Journal of Economics*, 36: 870-889.
- ¹¹Bertschek, I., & Kaiser, U. 2004. Productivity effects of organizational change: Microeconomic evidence. *Management Science*, 50: 394-404.
- ¹²Bharadwaj, S., Bharadwaj, A., & Bendoly, E. 2007. The performance effects of complementarities between information systems, marketing, manufacturing, and supply chain processes. *Information Systems Research*, 18: 437-453.
- ¹³Bierly, P. E., & Daly, P. S. 2007. Alternative knowledge strategies, competitive environment, and organizational performance in small manufacturing firms. *Entrepreneurship: Theory & Practice*, 31: 493-516.
- Bies, R. J., Bartunek, J. M., Fort, T. L., & Zald, M. N. 2007. Corporations as social change agents: Individual, interpersonal, institutional, and environmental dynamics. *Academy of Management Review*, 32: 788-793.
- Bin, G. 2008. Technology acquisition channels and industry performance: An industry-level analysis of Chinese large- and medium-size manufacturing enterprises. *Research Policy*, 37: 194-209.
- ¹⁴Black, S. E., & Lynch, L. M. 2001. How to compete: The impact of workplace practices and information technology on productivity. *Review of Economics and Statistics*, 83: 434-445.
- ¹⁵Bocquet, R., Brossard, O., & Sabatier, M. 2007. Complementarities in organizational design and the diffusion of information technologies: An empirical analysis. *Research Policy*, 36: 367-368.
- ¹⁶Bonaccorsi, A., & Thoma, G. 2007. Institutional complementarity and inventive performance in nano science and technology. *Research Policy*, 36: 813-831.
- ¹⁷Bresnahan, T. F., Brynjolfsson, E., & Hitt, L. M. 2002. Information technology, workplace organization, and the demand for skilled labor: Firm level evidence. *Quarterly Journal of Economics*, 117: 339-376.
- ¹⁸Brynjolfsson, E., & Hitt, L. M. 2003. Computing productivity: Firm-level evidence. *Review of Economics and Statistics*, 85: 793-808.
- ¹⁹Brynjolfsson, E., Renshaw, A. A., & Van Alstyne, M. 1997. The matrix of change. *Sloan Management Review*, 38 (2): 37-54.
- ²⁰Capelli, P., & Neumark, D. 2001. Do "high-performance" work practices improve establishment-level outcomes? *Industrial & Labor Relations Review*, 54: 737-775.
- ²¹Carmeli, A., & Tishler, A. 2004. The relationship between intangible organizational elements and organizational performance. *Strategic Management Journal*, 25: 1257-1278.
- ²²Caroli, E., & Van Reenen, J. 2001. Skill-based organizational change? Evidence from a panel of British and French establishments. *Quarterly Journal of Economics*, 116: 1449-1492.
- ²³Cassiman, B., Colombo, M. G., Garrone, P., & Veugelers, R. 2005. The impact of M&A on the R&D process: An empirical analysis of the role of technological- and market-relatedness. *Research Policy*, 34: 195-220.
- ²⁴Cassiman, B., & Veugelers, R. 2006. In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition. *Management Science*, 52: 68-82.
- Chandler, A. D. 1962. *Strategy and structure: Chapters in the history of the industrial enterprise*. Cambridge, MA: MIT Press.
- ²⁵Chenhall, R. H., & Langfield-Smith, K. 1998. The relationship between strategic priorities, management techniques and management accounting: An empirical investigation using a systems approach. *Accounting, Organizations and Society*, 23: 243-264.
- ²⁶Chesbrough, H. 2003. The governance and performance of Xerox's technology spin-off companies. *Research Policy*, 32: 403-421.
- Child, J. 1972. Organizational structure, environment and performance: The role of strategic choice. *Sociology*, 6: 1-22.

- ²⁷Choi, B., Poon, S. K., & Davis, J. G. 2008. Effects of knowledge management strategy on organizational performance: A complementarity based theory approach. *Omega*, 36: 235-251.
- ²⁸Christman, P. 2000. Effects of "best practices" of environmental management on cost advantage: The role of complementary assets. *Academy of Management Journal*, 43: 663-680.
- ²⁹Chung, S., Singh, H., & Kyungmook, L. 2000. Complementarity, status similarity and social capital as drivers of alliance formation. *Strategic Management Journal*, 21: 1-22.
- ³⁰Cockburn, I. M., & Henderson, R. M. 2001. Publicly funded science and the productivity of the pharmaceutical industry. *NBER Innovation Policy & Economy*, 1: 1-34.
- ³¹Colombo, M. G., & Grilli, L. 2005. Founders' human capital and the growth of new technology-based firms: A competence-based view. *Research Policy*, 34: 795-816.
- ³²Colombo, M. G., Grilli, L., & Piva, E. 2006. In search of complementary assets: The determinants of alliance formation of high-tech start-ups. *Research Policy*, 35: 1166-1199.
- ³³Colombo, M. G., & Mosconi, R. 1995. Complementarity and cumulative learning effects in the early diffusion of multiple technologies. *Journal of Industrial Economics*, 43: 13-48.
- ³⁴Cozzarin, B. P., & Percival, J. C. 2006. Complementarities between organisational strategies and innovation. *Economics of Innovation & New Technology*, 15: 195-217.
- ³⁵Cremers, K. J., & Nair, V. R. 2005. Governance mechanisms and equity prices. *Journal of Finance*, 60: 2859-2894.
- ³⁶Darnall, N., & Edwards, D., Jr. 2006. Predicting the cost of environmental management system adoption: The role of capabilities, resources and ownership structure. *Strategic Management Journal*, 27: 301-320.
- ³⁷Delaney, J. T., & Huselid, M. A. 1996. The impact of human resource management practices on perceptions of organizational performance. *Academy of Management Journal*, 39: 949-969.
- ³⁸De Miguel, A., Pindado, J., & De la Torre, C. 2005. How do entrenchment and expropriation phenomena affect control mechanisms? *Corporate Governance: An International Review*, 1: 505-516.
- Drazin, R., & Van de Ven, A. H. 1985. Alternative forms of fit in contingency theory. *Administrative Science Quarterly*, 30: 514-539.
- Edgeworth, F. Y. 1881. *Mathematical physics: An essay on the application of mathematics to the moral sciences*. London: Kegan Paul.
- Englert, B. G., Scully, M. O., & Walther, H. 1991. Quantum optical tests of complementarity. *Nature*, 351: 111-116.
- ³⁹Fabrizio, K. R., & Di Minin, A. 2008. Commercializing the laboratory: Faculty patenting and the open science environment. *Research Policy*, 37: 914-931.
- ⁴⁰Forman, C. 2005. The corporate digital divide: Determinants of Internet adoption. *Management Science*, 51: 641-654.
- ⁴¹Fosfuri, A., Giarratana, M., & Luzzi, A. 2008. The penguin has entered the building: The commercialization of open source software products. *Organization Science*, 19: 292-305.
- ⁴²Galia, F., & Legros, D. 2004. Complementarities between obstacles of innovation: Evidence from France. *Research Policy*, 33: 1185-1199.
- ⁴³Gao, L. S., & Iyer, B. 2006. Analysing complementarities using software stacks for software industry acquisition. *Journal of Management Information Systems*, 23: 119-147.
- ⁴⁴Gilsing, V., Noteboom, B., Vanhaverbeke, W., Duysters, G., & Van den Oord, A. 2008. Network embeddedness and the exploration of novel technologies: Technological distance, betweenness centrality and density. *Research Policy*, 37: 1717-1731.
- ⁴⁵Grandori, A., & Furnari, S. 2008. A chemistry of organization: Combinatory analysis and design. *Organization Studies*, 29: 459-485.
- Grant, R. M. 1991. The resource based theory of competitive advantage: Implications for strategy formulation. *California Management Review*, 33: 114-135.
- ⁴⁶Hashai, N., & Almor, T. 2008. R&D intensity, value appropriation and integration patterns within organizational boundaries. *Research Policy*, 37: 1022-1034.
- ⁴⁷Helfat, C. E. 1997. Know-how and asset complementarity and dynamic capability accumulation: The case of R&D. *Strategic Management Journal*, 18: 339-360.
- Hill, C. W., & Rothaermel, F. T. 2003. The performance of incumbent firms in the face of radical technological innovation. *Academy of Management Review*, 28: 257-274.
- ⁴⁸Hill, R. C., & Hellriegel, D. 1994. Critical contingencies in joint venture management: Some lessons from managers. *Organization Science*, 5: 594-607.

- ⁴⁹Hitt, L. M., & Brynjolfsson, E. 1997. Information technology and internal firm organization: An exploratory analysis. *Journal of Management Information Systems*, 14: 81-101.
- Hitt, M. A., Beamish, P. W., Jackson, S. E., & Mathieu, J. E. 2007. Building theoretical and empirical bridges across levels: Multilevel research in management. *Academy of Management Journal*, 50: 1385-1399.
- ⁵⁰Hitt, M. A., Bierman, L., Uhlenbruck, K., & Shimizu, K. 2006. The importance of resources in the internationalization of professional service firms: The good, the bad, and the ugly. *Academy of Management Journal*, 49: 1137-1157.
- ⁵¹Horgan, J., & Muhlau, P. 2006. Human resource systems and employee performance in Ireland and the Netherlands: A test of the complementarity hypothesis. *International Journal of Human Resource Management*, 17: 414-439.
- ⁵²Ichniowski, C., & Shaw, K. 1995. *Old dogs and new tricks: Determinants of the adoption of productivity-enhancing work practices*. Washington, DC: Brookings Papers on Economic Activity.
- ⁵³Ichniowski, C., Shaw, K., & Prennushi, G. 1997. The effects of human resource management practices on productivity: A study of steel finishing lines. *American Economic Review*, 87: 291-313.
- ⁵⁴Karimi, J., Somers, T. M., & Bhattacharjee, A. 2007. The role of information system resources in ERP capability building and business process outcomes. *Journal of Management Information System*, 24: 221-260.
- Kauffman, S. A. 1993. *The origins of order: Self-organization and selection in evolution*. New York: Oxford University Press.
- ⁵⁵King, D. R., Slotegraaf, R. J., & Kesner, I. 2008. Performance implications of firm resource interactions in the acquisition of R&D-intensive firms. *Organization Science*, 19: 327-340.
- Kirkman, B., & Law, K. 2005. International management research in *AMJ*: Our past, present, and future. *Academy of Management Journal*, 48: 377-386.
- ⁵⁶Krishnan, H. A., Miller, A., & Judge, W. Q. 1997. Diversification and top management team complementarity: Is performance improved by merging similar or dissimilar teams? *Strategic Management Journal*, 18: 361-374.
- Lachmann, L. 1947. Complementarity and substitution in the theory of capital. *Economica*, 14: 108-119.
- ⁵⁷Larsson, R., & Finkelstein, S. 1999. Integrating strategic, organizational, and human resource perspectives on mergers and acquisitions: A case survey of synergy realization. *Organization Science*, 10: 1-26.
- ⁵⁸Laursen, K., & Foss, N. J. 2003. New human resource management practices, complementarities and their impact on innovation performance. *Cambridge Journal of Economics*, 27: 243-264.
- ⁵⁹Lee, J. J.-Y. 2008. Complementary effects of information technology investment on firm profitability: The functional form of the complementarities. *Information Systems Management*, 25: 364-371.
- ⁶⁰Levin, N., & Ross, J. W. 2003. From the vendor's perspective: Exploring the value proposition in information technology outsourcing. *MIS Quarterly*, 27: 331-364.
- Levinthal, D. A. 1997. Adaptation on rugged landscapes. *Management Science*, 43: 934-950.
- Levinthal, D. A., & Warglien, M. 1999. Landscape design: Designing for local action in complex worlds. *Organization Science*, 10: 342-357.
- ⁶¹MacDuffie, J. P. 1995. Human resource bundles and manufacturing performance: Organizational logic and flexible production systems in the world auto industry. *Industrial and Labor Relations Review*, 48: 197-221.
- ⁶²Macky, K., & Boxall, P. 2007. The relationship between "high-performance work practices" and employee attitudes: An investigation of additive and interaction effects. *International Journal of Human Resource Management*, 18: 537-567.
- Matsuyama, K. 1995. Complementarities and cumulative processes in models of monopolistic competition. *Journal of Economic Literature*, 33: 701-729.
- Milgrom, P., Qian, Y., & Roberts, J. 1991. Complementarities, momentum and the evolution of modern manufacturing. *American Economic Review*, 81: 84-88.
- Milgrom, P., & Roberts, J. 1990a. The economics of modern manufacturing: Technology, strategy, and organization. *American Economic Review*, 80: 511-528.
- Milgrom, P., & Roberts, J. 1990b. Rationalizability, learning and equilibrium in games with strategic complementarities. *Econometrica*, 58: 1255-1277.
- Milgrom, P., & Roberts, J. 1994. Complementarities and systems: Understanding Japanese economic organization. *Estudios Economicos*, 9: 3-42.

- ⁶³Milgrom, P., & Roberts, J. 1995a. Complementarities and fit: Strategy, structure, and organizational change in manufacturing. *Journal of Accounting and Economics*, 19: 179-208.
- Milgrom, P., & Roberts, J. 1995b. Continuous adjustment and fundamental change in business strategy and organization. In H. Siebert (Ed.), *Trends in business organization: Do participation and cooperation increase cooperativeness?*: 231-258. Tübingen, Germany: J.C.B. Mohr.
- Miller, D. 1986. Configurations of strategy and structure: Towards a synthesis. *Strategic Management Journal*, 7: 233-249.
- ⁶⁴Miller, D. 1988. Relating Porter's business strategies to environment and structure: Analysis and performance implications. *Academy of Management Journal*, 31: 280-308.
- Miller, D., & Friesen, P. H. 1984. A longitudinal study of the corporate life cycle. *Management Science*, 30: 1161-1183.
- ⁶⁵Miotti, L., & Sachwald, F. 2003. Co-operative R&D: Why and with whom? An integrated framework of analysis. *Research Policy*, 32: 1481-1499.
- ⁶⁶Mithas, S., & Krishnan, M. S. 2008. Human capital and institutional effects in the compensation of information technology professionals in the united states. *Management Science*, 54: 415-428.
- ⁶⁷Moorman, C., & Slotegraaf, R. 1999. The contingency value of complementary capabilities in product development. *Journal of Marketing Research*, 36: 239-257.
- ⁶⁸Nerkar, A., & Roberts, P. W. 2004. Technological and product-market experience and the success of new product introductions in the pharmaceutical industry. *Strategic Management Journal*, 25: 779-799.
- Ng, D. 2003. The social structure of organizational change and performance. *Emergence*, 5: 99-119.
- ⁶⁹Padula, G. 2008. Enhancing the innovation performance of firms by balancing cohesiveness and bridging ties. *Long Range Planning*, 41: 395-419.
- ⁷⁰Parthasarthy, R., & Sethi, S. P. 1993. Relating strategy and structure to flexible automation: A test of fit and performance implications. *Strategic Management Journal*, 14: 529-549.
- ⁷¹Penner-Hahn, J., & Shaver, J. M. 2005. Does international research and development increase patent output? An analysis of Japanese pharmaceutical firms. *Strategic Management Journal*, 26: 121-140.
- ⁷²Poppo, L., & Zenger, T. 2002. Do formal contracts and relational governance function as substitutes or complements? *Strategic Management Journal*, 23: 707-725.
- Porter, M., & Siggelkow, N. 2008. Contextuality within activity systems and sustainability of competitive advantage. *Academy of Management Perspectives*, 22: 34-56.
- ⁷³Powell, T. C., & Dent-Micallef, A. 1997. Information technology as competitive advantage: The role of human, business, and technology resources. *Strategic Management Journal*, 18: 375-405.
- ⁷⁴Raff, D. 2000. Superstores and the evolution of firm capabilities in American bookselling. *Strategic Management Journal*, 21: 1043-1059.
- ⁷⁵Ravichandran, T., & Lertwongsatien, C. 2005. Effect of information systems resources and capabilities on firm performance: A resource-based perspective. *Journal of Management Information Systems*, 21: 237-276.
- Rivkin, J. W. 2000. Imitation of complex strategies. *Management Science*, 46: 824-844.
- Rivkin, J. W., & Siggelkow, N. 2003. Balancing search and stability: Interdependencies among elements of organizational design. *Management Science*, 49: 290-311.
- Roberts, J. 2004. *The modern firm: Organizational design for performance and growth*. Oxford, UK: Oxford University Press.
- ⁷⁶Roper, S., Du, J., & Love, J. H. 2008. Modelling the innovation value chain. *Research Policy*, 37: 961-977.
- ⁷⁷Rothaermel, F. 2001a. Complementary assets, strategic alliances, and the incumbent's advantage: An empirical study of industry and firm effects in the biopharmaceutical industry. *Research Policy*, 30: 1235-1251.
- ⁷⁸Rothaermel, F. 2001b. Incumbent's advantage through exploiting complementary assets via interfirm cooperation. *Strategic Management Journal*, 22: 687-699.
- ⁷⁹Rothaermel, F., & Boeker, W. 2008. Old technology meets new technology: Complementarities, similarities, and alliance formation. *Strategic Management Journal*, 29: 47-77.
- ⁸⁰Rothaermel, F. T., & Hess, A. M. 2007. Building dynamic capabilities: Innovation driven by individual-, firm-, and network-level effects. *Organization Science*, 18: 898-921.
- ⁸¹Rothaermel, F., & Hill, C. W. 2005. Technological discontinuities and complementary assets: A longitudinal study of industry and firm performance. *Organization Science*, 16: 52-70.

- Rothwell, R. 1975. Innovation and firm size: A case for dynamic complementarity; or, is small really so beautiful? *Journal of General Management*, 2: 5-25.
- ⁸²Ruiz-Navarro, J. 1998. Turnaround and renewal in a Spanish shipyard. *Long Range Planning*, 31: 51-59.
- ⁸³Schmiedeborg, C. 2008. Complementarities of innovation activities: An empirical analysis of the German manufacturing sector. *Research Policy*, 37: 1492-1503.
- ⁸⁴Schultze, U., & Orlikowski, W. J. 2004. A practice-perspective on technology-mediated network relations: The use of Internet-based self-serve technologies. *Information Systems Research*, 15: 87-106.
- Shane, S. 2001. Technology regimes and new firm formation. *Management Science*, 47: 1173-1190.
- ⁸⁵Siggelkow, N. 2001. Change in the presence of fit: The rise, the fall, and the renaissance of Liz Claiborne. *Academy of Management Journal*, 44: 838-857.
- Siggelkow, N., & Rivkin, J. W. 2005. Speed and search: Designing organizations for turbulence and complexity. *Organization Science*, 16: 101-122.
- Simon, H. A. 1945. *Administrative behavior*. New York: Macmillan.
- Simon, H. A. 1962. The architecture of complexity. *Proceedings of the American Philosophical Society*, 106: 467-482.
- ⁸⁶Somaya, D., Williamson, I. O., & Zhang, X. 2007. Combining patent law expertise with R&D for patenting performance. *Organization Science*, 18: 922-937.
- ⁸⁷Song, M., Droge, C., Hanvanich, S., & Calantone, R. 2005. Marketing and technology resource complementarity: An analysis of their interaction effect in two environmental contexts. *Strategic Management Journal*, 26: 259-276.
- ⁸⁸Swink, M., & Nair, A. 2006. Capturing the competitive advantages of AMT: Design-manufacturing integration as a complementary asset. *Journal of Operations Management*, 25: 736-754.
- ⁸⁹Tanriverdi, H. 2005. Information technology relatedness, knowledge management capability, and performance of multibusiness firms. *MIS Quarterly*, 29: 311-334.
- ⁹⁰Tanriverdi, H. 2006. Performance effects of information technology synergies in multibusiness firms. *MIS Quarterly*, 30: 57-77.
- ⁹¹Tanriverdi, H., & Lee, C. H. 2008. Within-industry diversification and firm performance in the presence of network externalities: Evidence from the software industry. *Academy of Management Journal*, 51: 381-397.
- ⁹²Tanriverdi, H., & Venkatraman, N. 2005. Knowledge relatedness and the performance of multibusiness firms. *Strategic Management Journal*, 26: 97-119.
- Teece, D. J. 1986. Profiting from technological innovation. *Research Policy*, 15: 285-305.
- ⁹³Tether, B., & Tajar, A. 2008. Beyond industry university links: Sourcing knowledge for innovation from consultants, private research organisations and the public science-base. *Research Policy*, 37: 1079-1095.
- ⁹⁴Tiwana, A. 2008a. Do bridging ties complement strong ties? An empirical examination of alliance ambidexterity. *Strategic Management Journal*, 29: 251-272.
- ⁹⁵Tiwana, A. 2008b. Does interfirm modularity complement ignorance? A field study of software outsourcing alliances. *Strategic Management Journal*, 29: 1241-1252.
- ⁹⁶Tiwana, A., & Keil, M. 2007. Does peripheral knowledge complement control? An empirical test in technology outsourcing alliances. *Strategic Management Journal*, 28: 623-634.
- ⁹⁷Toole, A. A. 2007. Does public scientific research complement private investment in research and development in the pharmaceutical industry? *Journal of Law & Economics*, 50: 81-104.
- Topkis, D. L. 1978. Minimizing a submodular function on a lattice. *Operations Research*, 26: 305-321.
- Topkis, D. L. 1987. Activity optimization games with complementarity. *European Journal of Operations Research*, 28: 358-368.
- ⁹⁸Tripsas, M. 1997. Unraveling the process of creative destruction: Complementary assets and incumbent survival in the typesetter industry. *Strategic Management Journal*, 18: 119-142.
- ⁹⁹Tzabbar, D., Aharonson, B. S., Amburgey, T. L., & Al-Laham, A. 2008. When is the whole bigger than the sum of its parts? Bundling knowledge stocks for innovative success. *Strategic Organization*, 6: 375-408.
- ¹⁰⁰Wang, L., & Zajac, E. J. 2007. Alliance or acquisition? A dyadic perspective on interfirm resource combinations. *Strategic Management Journal*, 28: 1291-1317.
- ¹⁰¹Werr, A., & Stjernberg, T. 2003. Exploring management consulting firms as knowledge systems. *Organization Studies*, 24: 881-908.
- ¹⁰²West, M. A., Guthrie, J. P., Dawson, J. F., Borrill, C. S., & Carter, M. 2006. Reducing patient mortality in hospitals: The role of human resource management. *Journal of Organizational Behavior*, 27: 983-1002.

- Whetten, D. A. 1989. What constitutes a theoretical contribution? *Academy of Management Review*, 14: 490-495.
- White, S. 2000. Competition, capabilities, and the make, buy, or ally decisions of Chinese state owned firms. *Academy of Management Journal*, 43: 324-341.
- ¹⁰³Whittington, R., Pettigrew, A., Peck, S., Fenton, S., & Conyon, M. 1999. Change and complementarities in the new competitive landscape: A European panel study, 1992-1996. *Organization Science*, 10: 583-600.
- ¹⁰⁴Wright, M., Liu, X., Buck, T., & Filatotchev, I. 2008. Returnee entrepreneurs, science park location choice and performance: An analysis of high-technology SMEs in China. *Entrepreneurship: Theory and Practice*, 32: 131-155.
- ¹⁰⁵Yadong, L. 2002a. Contract, cooperation, and performance in international joint ventures. *Strategic Management Journal*, 23: 903-919.
- ¹⁰⁶Yadong, L. 2002b. Product diversification in international joint ventures: Performance implications in an emerging market. *Strategic Management Journal*, 23: 1-20.
- ¹⁰⁷Zhu, K. 2004. The complementarity of information technology infrastructure and e-commerce capability: A resource-based assessment of their business value. *Journal of Management*, 21: 167-202.
- ¹⁰⁸Zott, C., & Amit, R. 2008. The fit between product market strategy and business model: implications for firm performance. *Strategic Management Journal*, 29: 1-26.