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European Business School

2009

Online at <https://mpra.ub.uni-muenchen.de/15666/>
MPRA Paper No. 15666, posted 18 Jun 2009 02:06 UTC

European Business School Research Paper Series 09-07

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A REVIEW OF THE EMPIRICAL LITERATURE ON

COMPLEMENTARITIES IN ORGANIZATIONS

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ABSTRACT

The concept of complementarity and its role in the design of organizations has enjoyed increasing attention over the past twenty years. We provide a systematic review of the empirical studies on complementarities in leading journals in management, economics and related disciplines that considers the nature of the factors among which complementarities are found to exist, and the effects of complementarities in organizations. Our findings suggest that complementarities result from the skilful matching of heterogeneous resources which generate positive returns above and beyond the effect of each resource generated on its own. In contrast, the empirical evidence on complementarities between individual organizational and HR practices in firms provides mixed conclusions. We show that complementarities are likely to materialize in complex systems of multiple design elements. Therefore, future research should aim at uncovering complementary effects among multiple elements that capture organizational systems better than a few selected elements only do.

Keywords:

Complementarities

Organizational Design

THE WHOLE IS MORE THAN THE SUM OF ITS PARTS – OR IS IT?

A REVIEW OF THE EMPIRICAL LITERATURE ON COMPLEMENTARITIES IN ORGANIZATIONS

Over the past twenty years, the concept of complementarity and its role in the design of organizations has gained widespread attention (Porter & Siggelkow, 2008). In its most general form, the notion of complementarity denotes the beneficial interplay of the design elements of a system where doing more of one thing increases the returns from doing more of the other (Milgrom & Roberts, 1994). However, complementarities may also entail negative consequences. For example, the existence of 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 (Gates, Milgrom, & Roberts, 1996; Matsuyama, 1995; Milgrom & Roberts, 1995b; Roberts, 2004).

In this paper, we provide a systematic review of the empirical literature in management and related disciplines on complementarities in organizations, two decades after Stanford economists Paul Milgrom and John Roberts began their seminal work in this area (Milgrom, Qian, & Roberts, 1991; Milgrom & Roberts, 1990a; 1990b; 1994; 1995a). Our work is motivated by the fact that complementarity theory, despite its many strengths, 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 to lay the basis for future theoretical work.

Our review suggests that complementarities have been investigated empirically from two different perspectives. Studies examining two- and three-way relationships among individual

elements provide fairly mixed evidence on the existence of complementarities in these relationships, in particular with respect to organizational policies, practices, structures and processes. Other types of elements (such as resources) are more likely (but by no means certain) to complement other factors. In contrast, studies investigating entire systems of complementary elements are largely unanimous in finding that organizations embodying such systems outperform others. We conclude that complementarities are systems-specific phenomena. Studies of relationships among individual elements or factors can offer valuable insight, but the failure of such a study to confirm complementary effects where it had expected them may mean that the full range of factors at work and their relationships have not yet been fully understood. Due to the difficulties involved in imitating complex systems, complementarities can be sources of significant competitive advantage for firms (Rivkin, 2000). On the flipside, their embeddedness in complex systems makes it hard for complementarities to be managed purposefully.

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 pay-off 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.

Drawing on the work of (Topkis, 1978; 1987), Milgrom, Roberts and their co-authors use the mathematical study of supermodularity on lattices to develop a formal model of complementarity (Athey, Milgrom, & Roberts, 1998; Milgrom & Roberts, 1994; Milgrom, Qian, & Roberts, 1991). 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, p. 5; 1990b). Although mathematical illustrations of complementarity typically refer to two activities only, complementarity theory relates not just to pairwise relationships between any two design choices, but among many elements simultaneously.

Complementarity theory breaks with the assumptions of traditional economics in several important ways. First, classical economics recognizes only two fundamental production factors (capital and labor), thus emphasizing relative resource homogeneity (Ng, 2003). In contrast, the concept of complementarities rests upon the insight that value creation results from combining heterogeneous 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 (Levinthal, 1997; Levinthal & Warglien, 1999;

Rivkin & Siggelkow, 2003). In addition, similar to some other economic models (e.g., the Leontief production function), the complementarity approach can 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). 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.

In sum, the fundamental contribution of complementarity theory is that it enables economists to model complex production systems as something more than the sum of their input factors in a mathematically tractable and rigorous manner. However, its model-oriented nature implies that complementarity theory provides little guidance with respect to the nature of organizational design elements among which complementary relationships exist. In this situation, researchers aiming to test the complementarities rely on identifying complementarities by their effects, rather than by direct observation. In addition, complementarity theory offers hardly any theoretical prediction about the conditions under which complementarities emerge, other than to say that the availability of heterogeneous resources constitutes a precondition for complementarities among these resources to exist.

DATA AND METHODS

Data collection

Our review covers empirical papers on complementarities published in six management-related disciplines, namely strategy, organization and general management, economics, marketing, accounting & finance, information systems and research & development (R&D) and innovation over the two decades from 1988 to 2008. In order to balance comprehensiveness and

manageability, we have focused on the top 80 academic journals by impact factor in the Social Sciences Citation Index (SSCI) 2007 ranking in these six subject areas. We searched the electronic library EBSCO for all papers in these 80 journals that contain the word stem “complement”.¹ 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%) i.e., 1398 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.² An analysis of the number of publications mentioning the notion of complementarities over time per discipline area suggests that interest in complementarity has increased continuously with a temporary peak in economics in the late 1990s, whereas, with 64 publications, interest in management reached a preliminary peak of in 2008. Overall, the evidence indicates that research interest in the concept of complementarity in economics has preceded its analysis in management. However, since 2007 the number of publications involving the notion of complementarity in management has exceeded the comparable number in economics.

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 below), which helped us to identify a further nine papers that deal with complementarities, some implicitly without using the term in the abstract. Second, to avert the possibility of publication bias (Hunter & Schmidt,

2004), we contacted the members of an established global network of academics in the field of organization theory via email. In our request, we asked whether the recipients were aware of any studies on complementarities that have not been published (such as works in progress, unpublished doctoral theses, or papers that had not made it into academic journals, e.g., due to empirical results that were not statistically significant). The respondents drew our attention to six papers, which we also added to our list, leading to a total of 1413 papers.

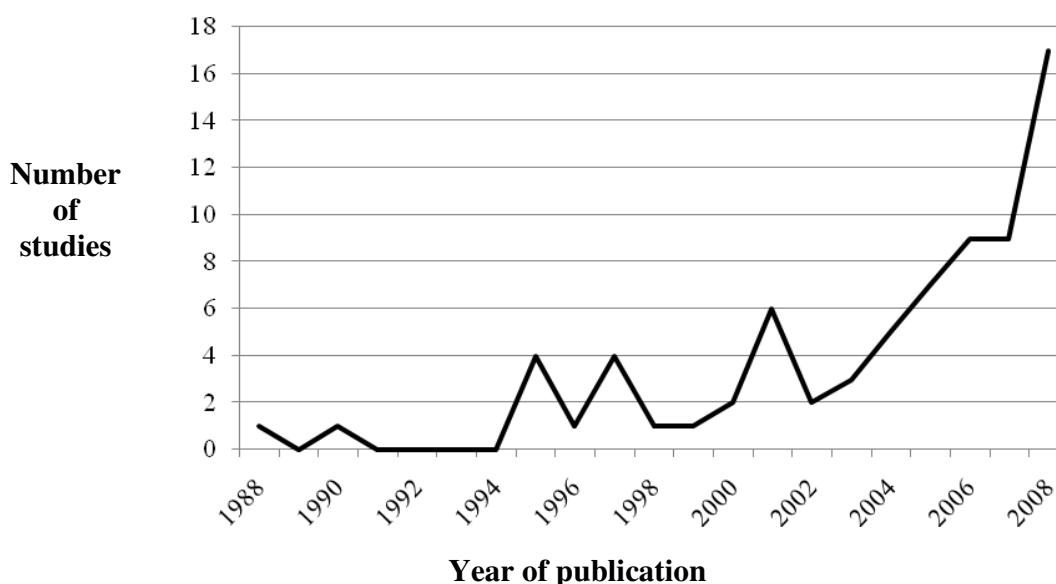
As we had chosen a wide search parameter, it was clear that only a relatively small proportion of these papers consisted of empirical studies on complementarities *per se*, rather than to merely use the word stem “complement” without devoting much attention to this concept. Therefore, we analyzed the abstracts of the 1413 papers, focusing on three search criteria. First, we selected only those papers that clearly involved *empirical* research on complementarity. We classified as empirical papers all those contributions that report original findings generated on the basis of primary or secondary data, including case studies and other qualitative studies. There were no experimental studies on complementarities. We did not include reviews of prior empirical work on complementarities (specifically, we excluded Ichniowski's (2003) review of empirical research on HRM systems in which complementarities play a major role), however, we worked through the reference list of such papers in order to ascertain that all original empirical work on complementarities was included in our data base. Our analysis revealed that about two thirds of the studies on complementarities are of an exclusively theoretical nature. Overall, the ratio of theoretical to empirical studies appeared to be higher in the economics than in the management journals. However, both the absolute and the relative number of empirical contributions appear to have increased considerably over time.

Second, 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

lead to the exclusion of some studies (e.g., White, 2000) that deal with “complementary assets” without, however, establishing any performance links. Third, due to our focus on management issues, we disregarded a few papers on complementarities among chemical and biological substances in agricultural and environmental economics. A total of 73 papers fulfilled all three criteria; these papers are the focus of our review below. We also draw additional insights from two simulation-based studies on complementarities (Rivkin, 2000; Siggelkow & Rivkin, 2005), although we did not include them among our empirical studies.

An analysis of the publication dates of the 73 studies suggests that over two thirds (70%) of these papers have been published in the last third of the 21-year period (1988-2008) we investigate i.e., between 2002 and 2008. Figure 1 shows that publication activity in this area has been particularly vibrant since 2006. 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 strategy, their organizational structures, and their market environment.

FIGURE 1
Overview of the studies (N=73) by publication year



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, or moderating factors in these relationships (for examples of such reviews see Tepper (2007) and Raisch & Birkinshaw (2008)). However, the notion of complementarities implies that it is impossible to identify “antecedents” that “lead to” complementarities, yet are separable from them. Rather, if a particular condition or factor affects or interacts with another one 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 interaction denotes the very essence of a complementary (or, in the case of a negative effect, a substitutive) relationship between the two conditions (or “elements” or “factors”) concerned. Therefore, we decided to deviate from the standard review approach described above, 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 i.e., whether the paper relates to phenomena on the firm-level (e.g., the interplay among organizational characteristics such as structural features, processes, or strategies), on the industry-level (e.g., the degree of munificence in an industry), or any other level, including those studies that concern several units of analysis.

Second, in order to gain greater clarity regarding the nature of the elements among which complementarities can be expected to exist, we categorized the 73 studies by the *type of elements investigated*, using four different groups with two subgroups each (see Table 1): Resources (distinguishing knowledge resources / capabilities and technological resources), organizational elements (distinguishing policies / practices and structures / processes), strategies (distinguishing corporate strategy and market strategy), and environmental factors (distinguishing location-related / geographical factors from market-related and regulatory factors).³ Each of these

categories, respectively sub-categories, have a long history of intellectual development (e.g., the discussion about optimal “fit” between strategy and structure, the resource-based view of the firm) which we cannot explore in detail here.

Third, we analyzed the *findings* of the 73 studies, distinguishing between two groups of papers depending on their *investigative approaches* (see Tables 2 and 3). Studies that take an *individual elements interaction approach* are those that analyze (potential) interaction effects between a limited number of clearly identifiable, well-described factors. 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 dominant statistical method applied consists of regression analysis, where the relationships between the elements investigated are usually modelled as interaction or moderation effects. There are only a few studies in this category that take approaches that are not regression-based (e.g., Grandori & Fumari’s (2008) who use Boolean comparative analysis; Brynjolfsson, Renshaw & Van Alstyne (1997) whose paper represents the only case-based study contained in this category). In contrast, studies that take a *systems approach* look at the relative performance outcomes of entire sets of multiple elements. Even in the qualitative studies within this category, individual elements (such an 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 (for prototypical studies, see Ichniowski, Shaw, & Prennushi (1997) and Horgan & Mühlau (2006)). In the first step, they use qualitative or quantitative (e.g., clustering) approaches in order to identify and describe systems as sets of multiple characteristics. This identification is based on whether a particular number, proportion or combination of factors are 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. 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 *individual elements interaction approach* and the *systems approach* allowed us to classify all of the 73 studies in an unequivocal way, with 44 studies belonging to the former group and 29 studies to the latter one.

RESULTS

Unit of analysis in the empirical literature on complementarities

Our review revealed that the dominant unit of analysis in the 73 studies is the *organization*. There are some studies that study complemenarities 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; Rothaermel & Hill, 2005); even Milgrom & Roberts (1995a), who exemplify the importance of complementarities in modern manufacturing, are primarily interested in the organizational design of firms in a given industry context, rather than in comparisons between sectors. Overall, well over 90% of the 73 studies use the firm as the primary unit of analysis (with the exception of Carmeli & 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). The clear majority of these studies focus on *within-firm* characteristics e.g., on the beneficial interplay among a set of human resources (HR) practices within an organization (Ichniowski, Shaw, & Prennushi, 1997) or on complementarities between a firm's technology

and its capabilities (Ravinchandran & Lertwongsatien, 2005). There are some studies that investigate the role of complementarities *between* firms (e.g., Arora & Gambardella, 1990; Cassiman, Colombo, Garrone, & Veugelers, 2005; 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 50-60% of all studies (as Kirkman & Law (2005) show on the basis of their review of articles published in the *Academy of Management Journal*). Overall, our analysis suggests that the empirical literature reviewed here conceives the notion of complementarities primarily as a ‘macro’, 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 a relatively short periods of time (as in the case of Brynjolfsson & Hitt, 2003; Tanriverdi & Lee, 2008) as their dependent variables. We found only one study (Siggelkow’s (2001) case study of Liz Claiborne) which employs a truly longitudinal perspective. Overall, the literature reviewed here provides little evidence on organizational change and transformation, or on the co-evolution of firms and their environments.

Types of elements investigated in the empirical literature on complementarities

As outlined above, we classified the 73 studies included in our data set by the *types of elements* among which the studies were searching for complementary relationships. The results of this analysis are contained in Table 1.

Inspection of Table 1 shows that the empirical research on complementarities has paid most attention to the relationships among particular *resources*, respectively to the relationships

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	Knowledge, capabilities	20.5	15.0	4.1	4.1	2.7	8.2	4.1	2.7
	T	Technology	15.0	5.4	2.7	8.2	-	1.3	-	-
Organization	P	Policies, practices	4.1	2.7	17.8	13.6	2.7	-	-	-
	S	Structures, processes	4.1	8.2	13.6	8.2	4.1	2.7	-	2.7
Strategy	M	Market strategy	2.7	-	2.7	4.1	1.3	1.3	-	-
	C	Corporate strategy	8.2	1.3	-	2.7	1.3	8.2	1.3	-
Environment	L	Location, geography	4.1	-	-	-	-	1.3	1.3	-
	R	Regulations, market conditions	2.7	-	-	2.7	-	-	-	1.3
			49.3	24.6	31.5	32.8	12.3	19.1	5.4	5.4
			58.9		45.2		30.1		10.9	

N=73 studies (100%)

Note: Totals for each combination of cells encircled in bold 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.

between the resources of an organization and its organizational design, strategy and/or environment. In total, 43 (58.9%) of the 73 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 have looked specifically at the role of *knowledge and capabilities* (as compared to *technological resources*) as potential constituents of complementary relationships. Of these studies, the clear majority finds 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, Christmann (2000) analyzes 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 have received significant attention in the empirical literature reviewed here relates to aspects of firms' *organization*. In total, 33 (45.2%) of the 73 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 *organizational policies and practices* as to *structures and processes*.

In comparison, we have found substantially fewer studies (22 in total, representing just 30.1% of the 73 papers) that include *strategic factors* among the elements among which complementary relationships are being investigated. In particular, with just 9 studies (12.3%), any potential complementarities between firms' *market strategies* and other elements have rarely been analyzed. Where dimensions of strategy were included among the factors investigated, these were typically aspects of a firm's *corporate strategy*, as in the case of Rothaermel and Hess' (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 two studies (Siggelkow, 2001; Tanriverdi & Lee, 2008) that have investigated complementary relationships between a firm's *corporate* and its *market-facing strategies*. There are also relatively few papers (6, representing 8.2% of the total) that have analyzed 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 optimal fit between 'strategy and structure' – dating back to Chandler's (1962) seminal work –, this result was surprising for us.

Finally, few studies (8 out of 73) have addressed complementary relationships between a firm's environment and other factors, such as its resources, organization or strategy, although Song, Droke, Hanvanich, & Calantone (2005) show that environmental conditions (such as degree of technological turbulence) may play an important role as facilitators or constraints in the emergence of complementarities. The relative scarcity of studies involving environmental factors might originate from the difficulties involved in multi-level studies (Hitt, Beamish, Jackson, & Mathieu, 2007).

Findings of the empirical literature on complementarities

In order to obtain an overview of the findings of the 73 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. 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 also noticed when a study found neither a complementarity nor a substitution effect between two or more factors.

Our analysis revealed marked differences in the findings between the studies taking the *individual elements interaction approach* and those adopting the *systems approach*. Therefore, we list the two groups of studies by their findings in different tables.

A broad comparison between Tables 2 and 3 suggests that the 44 studies taking the *individual elements interaction approach* provide far more mixed results with respect to any potential complementary relationships among the elements investigated than the 29 papers using the *systems approach*. Specifically, among the first group of studies, only 19 (43.1%) of the 44 studies find complementary relationships among all the elements they investigate. Five papers (11.3%) find, against their expectations, no complementary relationships among any of the factors studied, and the remaining 20 studies (45.5%) find evidence of complementary relationships between some elements, but substitution effects or no effects between others. In contrast, in the second group of studies, 24 (82.7%) of the 29 studies find unequivocally positive evidence of complementarities among all of the factors considered. Only one study in this group, namely Schultze and Orlikowski's (2004) case study on technology-mediated network relations did not find any evidence of complementarities at all (neither did they find substitution effects). Overall, this evidence suggests that the likelihood that a study finds complementary effects between two or more factors is at least partly driven by its investigative approach, and the empirical methods involved therein.

A closer analysis of the studies taking the *individual elements 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*

TABLE 2
Overview of the 44 studies applying the *individual elements interaction 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	12 34 52 59 59 66 67 69	17 52 59 58	32 46 53	41	62	39																			
	T	Technology	02 22 33 41 39 41 72	13 33 41 72	04 62																						
Organization	P	Policies, practices	05 68	17	05 68	33			15 21 31	16 28 43	10 11 28 31	11 15															
	S	Structures, processes	07 60	17	13 60	25 33 60	60	10 31	11 28 31	10 11 31	11 31	10 28															
Strategy	M	Market strategy	22					26	26		73	73															
	C	Corporate strategy	19 55 61 64	53 55	53 62		62												63								
Environment	L	Location, geography	09																				09				
	R	Regulations, market conditions	59										27														

Notes: Two-digit 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 29 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	24	29	24																						
	T	Technology	47	48	56		18	38																			
Organization	P	Policies, practices				08			01	35																	
	S	Structures, processes	29			08	14		36	37		36	70														
Strategy	M	Market strategy	49					20		20	45		49														
	C	Corporate strategy	65							57	70		57			03	06		06								
Environment	L	Location, geography	49	71	49	71											03										
	R	Regulations, market conditions	29								45												29				

Notes: Two-digit 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

provide insights on the performance effects of entire configurations of multiple elements. We discuss both aspects below, beginning with the former group of studies.

Studies taking the *individual elements interaction approach*. We highlight three results emerging from Table 2. First, the largest group of studies (31) taking the *individual elements interaction approach* involves at least one element of an organization's resource usage, in particular its knowledge or capability resources. Overall, most of these studies find that the combination of knowledge or capability resources with elements in *other* categories (e.g., organizational practices, structures, market and corporate strategies) constitutes a source of at least some complementarities among the elements concerned. For example, Rothaermel & Hess (2007) show that R&D capabilities complement the pursuit of biotech alliances in pharmaceutical firms, although they found substitutive effects between human capital intensity and biotech alliances. In contrast, combining resources of a particular type with other resources of a *similar* type within the same firm does not necessarily yield positive complementarity effects, as the example of Helfat's (1997) finding of no effects between general, firm-wide R&D capabilities and specific R&D capabilities in the area of coal conversion in petroleum companies shows. Somaya, Williamson and Zhang (2007) found substitutive effects, rather than complementarities, between two types of capabilities (R&D capabilities and patent law expertise) within the same firm. Our overall impression deriving from these observations is that complementarities involving resources are more likely to materialize within firms if these resources are matched with factors that are *dissimilar* from themselves. Complementarities appear to rely on resource heterogeneity; repeated investments in the same or substantially similar resources may well be subject to diminishing returns.

Second, inspection of Table 2 suggests that only five of the 19 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 namely, particular resources (Bendoly, Citurs, & Konsynski, 2007; Bresnahan, Brynjolfsson, & Hitt, 2002; Carmeli & Tishler, 2004; Cremers & Nair, 2005; Colombo & Mosconi, 1995). The other 14 studies involving at least one organizational element provide mixed results; i.e., 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 matching with other factors. A case-by-case analysis of the 18 papers involving organizational factors shows that around half 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; Macky & Boxall, 2007). These findings do not negate the possibility of complementary effects in high-performance work systems (see Laursen & Foss (2003); MacDuffie (1995)) rather, they suggest that such complementarities may only emerge once a full set of workplace practices are taken into account. We will return to this point below in the context of our report on the findings of the studies taking the *systems approach*.

Third, Table 2 shows that 10 studies on relationships between individual aspects of a firm's market or corporate strategy and other factors are available. Despite some "mixed" results, overall these studies cast a positive light on the possibility of complementary relationships

between a firm's strategy and other factors, such as its capabilities. Of particular prominence in this group are four studies on different types of strategic relatedness (e.g., product market relatedness, customer knowledge relatedness) in multi-business firms by Tanriverdi and his co-authors (Tanriverdi, 2005; 2006; Tanriverdi & Lee, 2008; Tanriverdi & Venkatraman, 2005). All four 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. Overall, the impression deriving from Table 2 is that a firm's pursuit of particular strategies may be beneficial in twofold ways, namely through their individual effects on performance on the one hand, and through complementary effects with the firm's resources, organization, or other elements of its strategy.

Studies taking the *systems approach*. As indicated above, 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 23 of the 29 studies in this group provide evidence of entirely positive effects, and even the six remaining papers find some complementary effects where they had expected them, in addition to some substitutive or insignificant effects. Specifically, there are 15 studies involving *organizational* elements (organizational policies/ practices and/or structures/processes), all of which come to unalloyed positive conclusions regarding the existence of complementary effects among the factors they discuss. Five of these studies (Ichniowski & Shaw, 1995; Ichniowski, Shaw, & Prennushi, 1997; Laursen & Foss, 2003; MacDuffie, 1995; Milgrom & Roberts, 1995a) focus primarily on systems of human resource management (HRM) practices, and two further studies, while not entirely focused on HRM, include in their systems descriptions aspects that are widely regarded as essential to HPWS approaches, such as group work (Bertschek & Kaiser, 2004) and decentralized

decision-making (Whittington, Pettigrew, Peck, Fenton, & Conyon, 1999). Overall, the systems perspective affirms the existence of complementary relationships among sets of multiple HRM elements. This result stands in marked contrast to the majority of studies investigating individual two- or three-way interactions among individual HRM and other organizational practices.

Further insights derive from an in-depth analysis of the six papers in the *systems approach* category that provide mixed results regarding the existence of complementary relationships. We found that all six papers analyze potential complementarities among firm characteristics, such as resource endowments, in *inter-firm relationships*, usually in the context of alliances or vertical (supplier-buyer) relationships. For example, Colombo, Grilli & Piva (2006) investigate 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. Belderbos, Carree & Lokshin (2006), in their study on the effects of joint cooperation strategies with competitors, customers and universities on productivity growth, provide evidence of some complementary and some substitutive relationships among these cooperative strategies. In contrast, the clear majority (17 out of 23) of the systems-based studies yielding unequivocally positive findings on the existence complementarities look at the relationships of elements *within* organizations. Overall, this evidence suggests that relationships among characteristics within the same organization are more reliable sources of complementarities than relationships between firms.

DISCUSSION

Summary and Implications for Further Research

Our review of the empirical literature on complementarities in this paper was motivated by the fact that complementarity theory (Milgrom & Roberts, 1990a; 1990b; 1994; 1995) is relatively silent with respect to the nature of the factors among which complementarities can be expected to exist, or on the conditions facilitating their emergence. In this situation, complementarities are hard to identify except for their performance effects (Athey & Stern, 1998). Consequently, factors that drive the emergence of complementary relationships can only be determined *after* their existence has already been inferred from their performance effects.

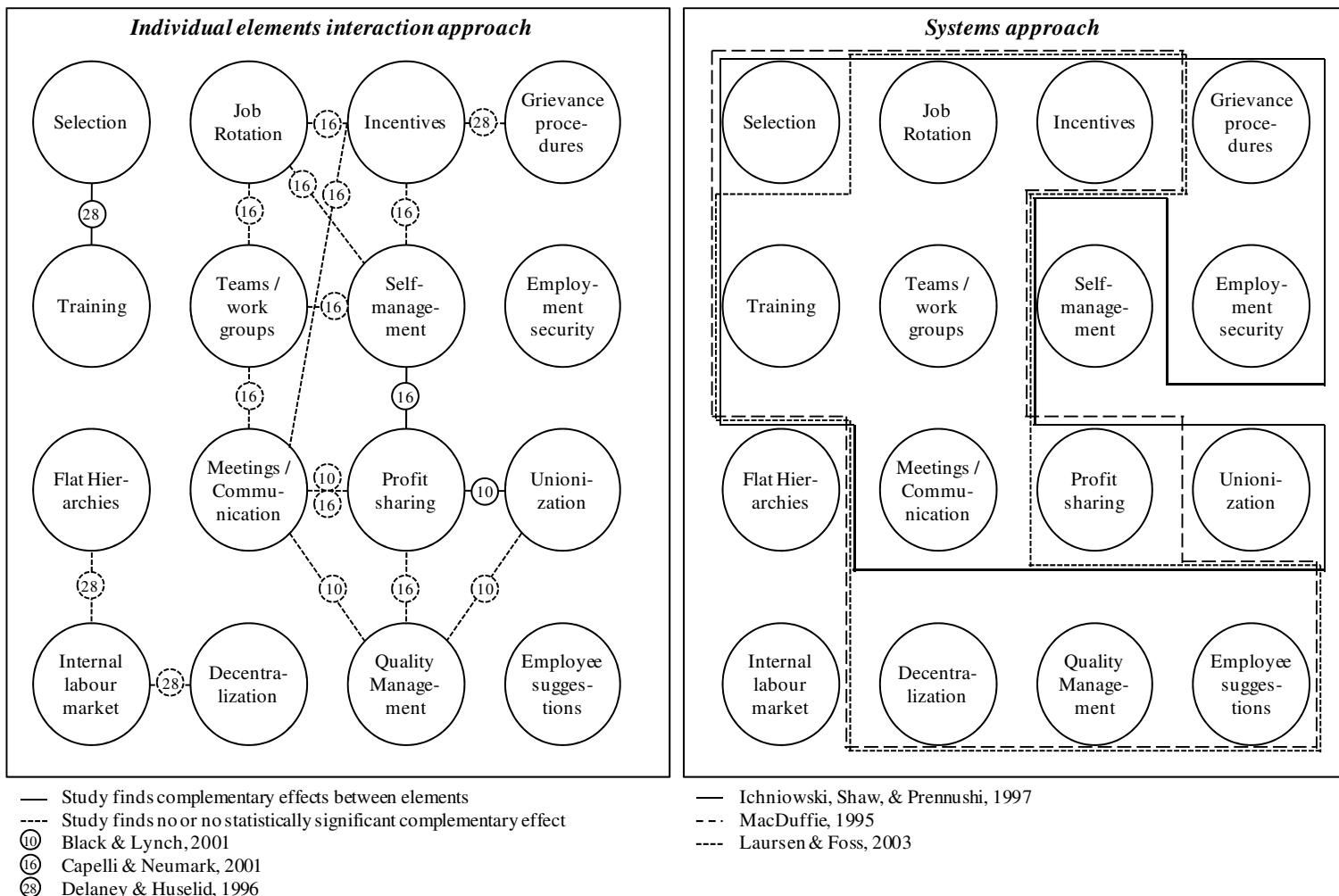
The 73 studies included in this review offer mixed results for complementarity theory. Clearly, complementarities among organizational design elements *may* constitute powerful performance drivers. However, the evidence in this respect is not unequivocal. The research reviewed here suggests that complementarities result from the careful matching of heterogeneous elements. A firm's human and technological resources, when combined with other factors such as policies or strategies, offer particularly promising candidates for the emergence of complementarities; a finding that should be of particular interest to proponents of the resource-based view of the firm (Barney, 1991). With respect to the combination of individual organizational practices, many studies provide evidence of mutually reinforcing effects (thus affirming the existence of complementarities), whereas others provide mixed or even negative findings. Overall, our review of the 44 studies taking the *individual elements 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 contrast, studies that do not focus on one-on-one relationships among a limited set of factors, but on the performance of entire *systems* of elements within firms, provide substantially more positive results. In the following discussion, we focus on this contrast between the studies taking the *individual elements interaction approach* and those adopting the *systems approach*.

We were particularly intrigued by our finding that even studies looking at the same topic area (however broadly defined) may come to fairly different conclusions regarding the existence of complementarities, depending on their investigative approach. We use the example of the literature in HRM/workplace practices to illustrate this argument. As described in the Results section, 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 relationships among individual HR practices are fairly inconclusive. Figure 2 presents a graphic comparison between three studies using the *individual elements interaction approach* (Black & Lynch, 2001; Capelli & Neumark, 2001; Delaney & Huselid, 1996) and three papers using the *systems perspective* (Ichniowski, Shaw, & Prennushi, 1997; Laursen & Foss, 2003; MacDuffie, 1995).

While each of the six studies involves only a subset of the 16 elements depicted in Figure 2, both groups of studies discuss largely the same type of elements. The three papers in the first group of studies each investigate between four (Black & Lynch, 2001; Delaney & Huselid, 1996) and ten (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 eight (Laursen & Foss, 2003) and ten (Ichniowski et al., 1997; MacDuffie, 1995) factors in describing and identifying whether coherent bundles of HRM-related practices were present in the organizations contained in their samples. While the choice of the factors varies somewhat

FIGURE 2
Comparison of elements combination between the two investigated approaches



from study to study, five factors (training, incentives, job rotation, teams/workgroups, 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 *individual elements interaction approach*. The papers applying the *systems perspective* yield substantially more positive evidence on the prevalence of complementarities in organizations, but they leave the question of the role of each factor in driving the emergence of such complementarities largely unanswered.

We conclude from this comparison that the question of whether a study finds evidence of the existence of complementarities between particular factors is at least partly contingent on the perspective it takes. From our perspective, complementarities are primarily systems characteristics. They emerge through complex interactions among multiple elements. The analysis of one-on-one relationships among individual factors may produce 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 interactions (or the absence thereof) with other elements outside the study's focus. In this respect, Ichniowski et al. (1997) finding that the addition of some practices to an existing set of HR policies and procedures may well *reduce* the performance of the HR system, and that only implementing a fully-fledged, comprehensive system of HR practices exerts full benefits, is particularly instructive. Establishing entire systems of mutually reinforcing design elements leads not only to enhanced operational performance, but has additional benefits in that complex systems provide protection against imitation by competitors (Rivkin, 2000).

In this vein, we believe that future empirical research should take an even broader approach to complementarities, taking resource-related, organizational, strategic and environmental factors into account. To give a practical example, in their seminal paper Milgrom & Roberts (1990a) study the emergence of modern manufacturing, using the case of the Ford Motor Company in the

early years of its existence. They argue that the interplay of specific resources (e.g., specialized labor), the application of particular organizational and work practices (e.g., use of the standardized line production principles, close supervision) and firm strategies (e.g., focus on a particular price segment) were highly complementary – but only so under the demand conditions at the time (e.g., high demand for sturdy, reliable cars with no frills from an emerging, increasingly affluent middle class in a geographically dispersed country). According to this perspective, complementarities existed among resources, organizational practices, strategies *and* demand conditions (and probably other factors, such as the institutional environment), rather than among resources and organizational and work practices *only*. In sum, we believe that research should aim at uncovering complementarity effects among multiple elements that capture organizational systems better than a few selected elements only do.

Our review has also shown that most empirical studies on complementarities assume a cross-sectional perspective, and that they largely use performance measures of various types. Given that complementarity theory 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. Overall, we believe there are still ample opportunities for valuable empirical (and theoretical) research on complementarities in management and related disciplines.

Implications for Managerial Practice

Our argument above that complementarities are primarily systemic phenomena clearly raises doubts about the extent to which complementarities can be managed purposely. Complementarity

theory can be understood as a siren call against the notion of “best practices”, which supposedly enhance performance regardless of the circumstances in which they are applied. The complementarity perspective 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, 43 of the 73 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 24 studies found mixed evidence. In comparison, only six studies found no or even negative effects where they had expected positive ones. Therefore, complementarities, although clearly not ubiquitous, appear to be widespread, suggesting that the development of organizational systems embodying such complementarities is not impossible. 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, an analysis of individual studies (e.g., Carmeli & Tishler, 2004) suggests that these effects can be substantial. Organizational development towards 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. For example, as the example of Milgrom and Roberts' (1990a) example of Ford mentioned above 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. Complementarity theory 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.

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FOOTNOTES

¹ In total, EBSCO lists 12135 papers published during the 1988 to 2008 period in all discipline areas. An analysis of subject area of these papers suggests that about one third of these contributions have been published in technical and engineering-related journals. However, we found publications containing the word stem “complement” across all disciplines, indicating that the notion of complementarity is used widely.

² A full overview of the number of publications by journal in the six subject areas is available from the authors.

³ A study can belong to several of these categories simultaneously e.g., when it investigates the relationship between two or more types of resource endowments of a firm (e.g., managerial capabilities and human capital; see Carmeli & Tishler, 2004) as well as between these resources and its organizational policies and practices (e.g., in the case of Carmeli & Tishler [2004], its auditing policies); therefore, the total/subtotal figures in Table 1 differ from the number of studies contained in the individual cells.