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Connectivity knowledge and the degree of structural formalization: a contribution to a contingency theory of organizational capability

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Abstract

The objective of this study is to develop a contingency theory of organizational capability based on the identification of decision variables relevant to the design of firms. The paper supports a model in which superior performance is the result of the proper fit between applied knowledge and organizational structure. More specifically, the study shows that the degree of structural formalization adopted by an organization reflects how knowledge controls the flow of action. The study identifies a functionally distinctive type of knowledge used to regulate the temporal order of tasks called *connectivity knowledge*. The influence of connectivity knowledge on the degree of organizational formalization is empirically tested on data collected in the healthcare sector. Applying a longitudinal logistic regression model on a dataset of 105 hospitals located in New York and New Jersey, this paper measures and compares the odds of key therapeutic tasks being provided by formalized hospital arrangements in which physicians work as employees instead of as autonomous professionals. Empirical results provide preliminary support to the core hypothesis correlating the volume of connectivity knowledge applied in therapeutic services to the degree of structural formalization adopted by a hospital.

Keywords: Knowledge management, Capability theory of the firm, Contingency theory, Organizational design

Introduction

Strategic management has experienced considerable change in recent decades (Mahoney and McGahan 2007; Nerur et al. 2008). Empirical evidence showing that firms are capable of sustaining advantage in competitive markets has produced various theories focused on firm-specific sources of superior performance (Ramos-Rodrigues and Ruiz-Navarro 2004). Long preoccupied with competitive analysis, strategists are becoming increasingly interested in the role played by organizational capability in generating performance heterogeneity. Organizational capability broadly refers to the ability of firms to coordinate value-adding jobs (Dosi et al. 2000). From this perspective, successful firms are not only those jockeying for market positions but also those capable of applying idiosyncratic expertise that is difficult to transfer across organizational boundaries (Zander and Kogut 1995). A capability theory applied to the strategic management field seeks

primarily to explain how organizations outperform each other by adopting more efficient and effective value-creating activities (Cockburn et al. 2000).

The contingency perspective is useful in refining the capability theory of the firm (CTF). A contingency model of organizational capability is particularly useful in identifying decision variables pertinent to the proper design of firms (Burton and Obel 2004). The recurrent characteristic of the contingency approach to organizational theory is to reject one best way to organize firms and suggest different alternatives according to the circumstances. The theory advocates that organizational effectiveness results from fitting characteristics of the organization to key selected factors related to particular challenges faced by the organization (Donaldson 2001). The contingency perspective of the firm has been reinvigorated in the field of strategic management by the work of Birkinshaw et al. (2002), which emphasizes the relationship between knowledge characteristics and organizational structure within the context of multinational operations interested in diffusing practices. Nickerson and Zenger (2004) also emphasized the role played by knowledge formation in the selection of organizational design based on the characteristic of search for solutions. More recently, Burton et al. (2015) developed a multi-contingency model in which information and knowledge are core contingency factors influencing the design of organizations. The purpose of the present study is to extend this line of inquiry to new arenas of conceptual and empirical development.

In contrast to previous works on the knowledge-based contingency theory, the focus here will not be on *searching* for solutions or *diffusion* of practices but on the *application* of knowledge. All of these other perspectives on knowledge are useful in examining the effectiveness of organizations and constitute subsections of a broader management field of investigation (Conner and Prahalad 1996). Nevertheless, they do not cover all the issues pertinent to the economics of knowledge management. Knowledge creation facilitates organizational flexibility and adaptation (Nonaka and Takeuchi 1995), whereas knowledge transfer facilitates organization growth and expansion (Zander and Kogut 1995). We also need to fully understand the process of knowledge application, which is not as trivial a process as usually assumed in strategic management. Organizations skilled in using knowledge for diverse economic reasons—either in manufacturing or service industries—still may struggle to adapt already existing knowledge to new problems. Knowledge, as any other resource, needs to be adequately processed and organized in order to generate valuable outcomes. Simply creating and diffusing knowledge is not sufficient for generating value to end consumers (Becerra-Fernandez and Sabherwal 2001; Pertusa-Ortega et al. 2010).

The main argument of the paper is as follows: One of the most relevant contingency factors to consider in the design of organizations is the knowledge required to structure productive tasks. Knowledge is a special resource for problem-solving activities and it performs a strategic role in allowing firms to create valuable products or services according to the industry of operations. Knowledge is applied for specific purposes in conducting complex and uncertain jobs. The volume of knowledge required to solve difficult problems generates recurrent organizational challenges regarding how to best develop and deploy cognitive capabilities. Choosing the ideal structural form for a firm is a strategic decision because it deals with the challenge of selecting how to apply knowledge to create value (Mintzberg 1979; Lam 2000). For instance, firms have diverse options for allocating cognitive capabilities according to how jobs are designed and

implemented. This is not only a technical problem but also an important managerial one given that knowledge application processes also involve decisions about how authority is distributed across job positions, how responsibility is allocated within performing teams, how rules of conduct are established, how tasks are coordinated in time, and how performance is monitored and rewarded (Burton and Obel 2004). We claim that superior organizational capabilities are the result of the proper fit between applied knowledge and organizational structure.

In the next section, we discuss the contributions and shortcomings of the received capability theory of the firm (CTF) and suggest how it can potentially benefit from a knowledge-based contingency perspective. Then we position the current research project within the tradition of the contingency theory of organizations and promote a model in which a special type of knowledge (i.e., connectivity knowledge) informs the organizational design. In subsequent sections, we fully conceptualize the model and test it empirically based on data collected in the healthcare industry. Empirical results provide preliminary support for the core hypothesis correlating the volume of connectivity knowledge applied in therapeutic services to the degree of structural formalization adopted by a hospital. The final section of the paper is dedicated to discussing results and suggesting future developments in the research project.

The contingency approach applied to CTF

The objective of the current paper is to advance rather than to replace the existing capability theory of the firm (CTF). CTF was born from the idea that firms play a functional role in the economy. Firms are capable of performing sophisticated tasks such as building automobiles or computers, or flying us from one continent to another (Dosi et al. 2000). Firms conduct a variety of transformative processes that provide valuable goods and services to society (Nelson and Winter 1982). They are capable of absorbing knowledge and rearranging it in the form of different goods and services. Knowledge is specifically relevant in sustaining organizational capability due to its role in conditioning how other resources are applied (Winter 1998). Knowledge is a key input factor given that it enables the firm to transform other inputs into valuable outputs (Arrow and Hahn 1971; Nelson and Winter 1982). Superior firms are those capable of adapting their organizational structure to the type of knowledge required to perform value-adding tasks. In our model, the knowledge content is less relevant than how pieces of knowledge are configured and interconnected with each other as they are applied to problem-solving tasks.

CTF emphasizes the corporate function of knowledge management. It relies on the assumption that managerial processes are essential for improving organizational performance in the face of increasingly difficult problems. Its main arguments can be summarized as follows: Knowledge increases organizational effectiveness when it is less dependent on individuals and supported by routines (Winter 2003). From the perspective of CTF, tight vertical integration is usually the preferred method for tackling the demands of complex activities and uncertain outcomes. Knowledge management benefits from the application of protocols and shared language that facilitate coordination (Grant 1996; Kogut and Zander 1992; Monteverde 1995; Moran and Ghoshal 1996). Essentially, this model points out that hierarchical systems are better for knowledge management than spontaneous networks of individual workers (Nickerson and Zenger

2004). From the perspective of traditional CTF, the *centralized* organization is usually preferable to the *decentralized* one, given that the latter tends to be inefficient in tasks requiring the creation, application, and/or transfer of sophisticated knowledge. Reducing internal costs generated by coordinating knowledge across units tends to make centralized structures more prone to generate knowledge with larger and broader impact (Argyres and Silverman 2004).

While CFT provides a useful generalization, here we highlight the need to moderate its core tenets in order to minimize the limitations and constraints of a monolithic theory of organizational structure. There are situations in which the benefits of the centralized structure are minimized or become too costly to justify a long-term adoption. Acknowledging that certain structural solutions might not be appropriate for all types of knowledge management is vital to envisioning alternative approaches to efficient and effective problem solving. Ultimately, being able to customize and adapt the resource base to needs is what allows a firm to sustain its competitive advantage over time (Teece 1996). In addition, the ability to manage resources in a deliberate manner assists in balancing the costs of a capability and its value (Winter 2003).

We suggest a slightly (but fundamentally) different theoretic perspective on how to apply knowledge through alternative organizational configurations. The key is to identify core parameters that make either one or the other form of governance mode more conducive to effectiveness. It is true that decentralized organizations have difficulty in dealing with more complex coordination, but they also have relevant strengths in knowledge management. Decentralized organizations are superior to centralized ones in ways that might be strategic on certain occasions. They require fewer administrative expenses, allow higher levels of customization, and are more prone to organic adaptation, which make them potentially more efficient and even more effective than centralized organizations in performing certain tasks (James 2003). They are also better equipped to promote psychological empowerment (Mathieu et al. 2006) and foster positive emotional outcomes (Ryan and Deci 2000), which are essential components of a healthy and sustainable organizational climate. There is also evidence that decentralized structures encourage a more proximate search for knowledge, which promotes the development of in-depth capabilities (Argyres and Silverman 2004).

A contingency perspective of the organizational capability informs us that there is no best way to organize the application of knowledge, but many possible ones. For this reason, it is our purpose to convert CTF into a decision model (Burton et al. 2015). This means that it should not advocate either one or other organizational form as the best, but identify which one is the most appropriate according to the demands of the task. The features of the cognitive task are particularly relevant to our modeling purposes. We propose that the choice of the best organizational structure depends on the ability to manage increasing *volumes* of knowledge required to solve a difficult problem. With volume, there is an increasing need to combine, integrate, and amalgamate different parts of the relevant knowledge body, ultimately affecting how knowledge is organized for productive purposes. We believe that adopting a contingency perspective is useful to relativize the need for "more" centralization even in face of the evidence that more centralization usually is accompanied with a greater capability of knowledge application through the deployment of coordinating tasks. The contingency perspective highlights the need to exercise judgment in choosing the best organizational

arrangement. More structured organizations generate benefits in knowledge management, but they also face additional sources of inefficiencies, expenses, and risks. Trade-off analysis is essential to any contingency approach.

One important step in overcoming this inherent shortcoming in the received CTF theory is to replace the core variable describing the degree of structuration of an organization. Instead of *centralization*, we should promote the notion of *formalization* as the main feature describing organizational architecture. Centralization refers to the location of decision-making rights, whereas formalization refers to the codification of decision-making processes (Burton et al. 2015). In many ways, these two organizational variables get confused because centralization tends to occur through formalized procedures that often standardize or reduce the discretion of decision-making at the level of the task (Pertusa-Ortega et al. 2010). However, this connection is not necessarily true in all conditions (Kim et al. 2003). Decision power is relevant to formalizational issues, but power can be distributed in multiple forms, meaning that it can be implemented in either centralized or decentralized ways (Nickerson and Zenger 2004). A good example of this phenomenon is the multidivisional structure that makes the firm more formalized, but also more decentralized at the same time (Chandler 1962). For instance, structural stability and flexibility can be combined in a reward system that favors cooperation across unit boundaries (Gold et al. 2001). Consequently, we suggest changing the emphasis on how organizational structure is depicted for the sake of knowledge application. Instead of focusing on a continuum of centralization, we prefer to deal with a continuum of formalization.

Formalization of the organization deals with issues related to well-defined jobs as well as the adoption of regulations, decision-making rules, and policy implementation. While informal organizations are usually decentralized (because decision rules derive from individual skills), more formalized organizations can be either centralized or decentralized without affecting their fundamental character. Decision rights might be allocated either up or down along the hierarchy of jobs depending on the degree of complexity of the task. Invariably, in industries in which tasks are highly complex, organizations are compelled to decentralize the decision-making process to individuals closest to the action. The decentralization of decision rights should not necessarily affect the process of establishing the nature of relationships and responsibilities within the firm. In complex industries, for instance, hierarchical organizations might be also decentralized, as in the case of some professional organizations centered on highly intellectualized workers capable of operating autonomously based on their levels of education and experience. The focus of formalization is not the relationship between superior and subordinate, but the relationship between worker and job, which also affects the boundaries of the firm. If decision rules are firm-specific, then there is a need for more control. More formalized organizations require the *internalization* of tasks, while less formalized organizations permit the *externalization* of tasks (i.e., the professional conducting the action does not need to be a legal member of the organization). This difference also distinguishes our approach from that of traditional organizational economics in the sense that we are not concerned with the cost of transactions but with the cost of cognitive efforts. In a formal but decentralized organization based on professional work, decisions are not necessarily determined from above, but shaped through the adoption of best practices and guiding policies.

Knowledge as a contingency factor

The main goal of the contingency approach to organizational theory is to tailor the structure of the organization to external sources of uncertainty and complexity (Perrow 1967; Thompson 1967; Lawrence & Lorsch, 1967). Organizations are open systems, vulnerable to environmental contexts. Different conditions lead to the selection of different organizational designs. The core teaching of the contingency theory is that organizations vary in their abilities both to process information about the environment and to coordinate internal activities required for survival.

Among the traditional contingency factors, technology (understood broadly as *applied knowledge*) plays a promising role because it directly affects the conduct of tasks required to solve valuable productive problems (Donaldson 2001). The logical argument underlying the connection between technology features and organizational structure is that the right match increases the ability of firms to conduct transformation processes compatible with the nature of production. One of the most important theoretical approaches linking technology to structure was originally suggested by Joan Woodward (1980), who claimed that it was possible to develop generalizations about the formal composition of a company based on its fit with different technologies. She essentially argued that different technologies directly determine certain aspects of the organizational structure, such as span of control, centralization of authority, and the formalization of rules and procedures. Perrow (1967) also emphasized the central place occupied by technology in the transformation process, affirming that the type of technology used by the organization determines the most effective structure for successful performance. Other contingency-oriented authors such as Thompson (1967) and Galbraith (1973) also emphasized the role of organizations in controlling increasing degrees of complexity through different types of technology.

Taken together, these studies on technology as a contingency factor demonstrate that certain organizational structures are more appropriate for dealing with uncertainty and complexity than others (Tushman and Nadler 1978; Keller 1994; Larkey and Sproull 1984). This connection has been corroborated by additional research focused on the need to provide information-processing capabilities to decision makers so that tasks can be performed accordingly based on the underlying objectives (Daft and Lengel 1986; Habid and Victor 1991; Rogers and Bamford 2002; Wolf and Egelhoff 2002). As the amount of uncertainty and complexity increases, so too does the imperative for increased information-processing capacity (Burton and Obel 2004). When an objective calls for interdependent activities, for instance, the need to communicate creates difficulties across tasks performed by separate individuals. The organization needs to rely on specific communication protocols between operational units. The ability to deal with input uncertainty and complexity requires activities such as collecting appropriate information, applying information in a timely fashion, transmitting information without distortion, and managing high volumes of information.

The contingency method of dealing with uncertainty and complexity by tailoring organizational structure to features of the information-processing technology is useful but inevitably incomplete. Organizations operating in complex industries require more than just communication functions; they also require computational operations based on previously accumulated knowledge. The ability to process information faster and more accurately, for instance, cannot resolve complex problems unless it is guided by

knowledge either acquired from outside or created within the firm (Montibeller et al. 2006). While *information* indicates what something means, *knowledge* addresses how to do something (Zander and Kogut 1996). This distinction is highly relevant for the sake of making architectural decisions about the organizational form.

Technology applied to knowledge application is less mechanical or physical than other forms of information technology, at least at this time in history. A broad notion of technology encompasses computer hardware and software, but it is less about the computer itself and more about the knowledge underlying the computational activity. This conceptual definition of technology allows more flexibility in recognizing the various ways technology matters. Computation occurs within information technologies, but it also occurs within the minds of individuals or even as the combination of cognitive and behavioral activities conducted by a team (Forrester 2000; Hutchins 1996; Power and Waddell 2004). These alternative mechanisms of computation based on cognitive skills supplied by individual members of the organization deal with more complex socio-technical arrangements that combine human and machine competencies into a more comprehensive technological apparatus. This dimension of operations based on cognitive functions conducted by teams can profoundly influence the selection of the best organizational design.

The ways in which pieces of applied knowledge possessed by different individuals interact and complement each other have an important impact on organizations. If for every task there is a corresponding knowledge set underlying it, these tasks, along with their knowledge sets, can be combined to conduct increasingly sophisticated behaviors. The underlying knowledge guiding tasks is specific to each particular problem, but we can try to create a science of applied knowledge if the theory focuses exclusively on the structural configuration of knowledge. From a logical perspective, pieces of knowledge are connected to each other temporally within a job: they are conducted either concurrently or sequentially in reference to each other (Thompson 1967; Marks et al. 2010; Burton et al. 2015).

Ordering of tasks within or across jobs has an inherent dimension of temporality that is relevant to the organization given that some of those tasks have to perform coordinating functions expressed through *time-based regulations*. For this reason, we infer that the temporal connectivity of tasks is enabled by a distinct kind of knowledge with a special functional role in value creation. We call the knowledge promoting standard tasks as *content* knowledge, whereas this other kind of knowledge promoting regulatory tasks (or meta-tasks) we call *connectivity* knowledge. The structure of the firm is essentially the reflection of demands generated by the need to apply the latter type of knowledge to the process of configuring a string of interconnected tasks.

The application of knowledge requires a method of execution that is also dependent on knowledge, meaning that content knowledge depends on an additional type of knowledge in order to be properly used in practice. These additional pieces of knowledge correspond to technologies (or techniques) that allow already existing knowledge to be adapted to particular uses. This specific type of knowledge plays the function of connecting existing pieces of knowledge into a coherent temporal flow of action. Another way of putting it is to recognize that *time* has a relevant role in organizing the use of knowledge for productive processes. Knowledge effectiveness depends on crafting a logical sequence of cognitive steps required to solve a problem or accomplish

an objective. For this reason, the application of knowledge through specific cognitive mechanisms depends on an appropriately configured organizational structure that governs the "temporal ordering of tasks."

The distinction between different *functions* of knowledge justifies the adoption of a terminology that makes a clear distinction between content knowledge dedicated to tasks and connectivity knowledge dedicated to meta-tasks (or how tasks are temporally connected to other tasks in the same job or across jobs). In order to work as a productive resource, knowledge applied to tasks needs to be adequately adapted to the particular objectives of the job to be done. By tailoring previously acquired knowledge to the act of selecting appropriate behaviors according to the nature of problems, the decision maker (as an individual or team) engages in an active and dynamic intellectual effort. The ability to apply the same knowledge to a variety of problems necessitates a complex and highly adaptive cognitive process that combines prior accumulated knowledge together with new collected information about the problem at hand (Sweller 1988).

Most of the cognitive mechanisms employed today to solve complex problems are still under the full control of individuals, in the form of psychological processes and internalized human capital. However, the exercise of individual cognitive capabilities is guided by the organizational context in which the intellectual job is performed. As task complexity increases, the need to apply connectivity knowledge also increases. Up to a certain point, the selective allocation of attention to different types of knowledge can be done by individual agents separately from each other. However, as the amount of knowledge increases beyond a certain threshold, there is a need for a more formal division of the cognitive labor. Increasing volumes of connectivity knowledge means that the organization has to make sure that the necessary cognitive capability is in place. One of the consequences of this institutionalization of cognitive functions is the adoption of increasing degrees of structural formalization responsible for developing and deploying relevant cognitive capabilities.

The economics of knowledge application

Figure 1 below displays the model of organizational capability in a simplified manner in which knowledge is a resource of production (Postrel 2002). It represents the nature of a resource application process based on input-process-output (IPO) episodes composed of three components: (a) the core input from the task environment (represented by knowledge), (b) the transformation process (represented by the organizational structure), and (c) performance outcomes (represented by some measurement of

Fig. 1 The contingent model of organizational capability (restricted model)
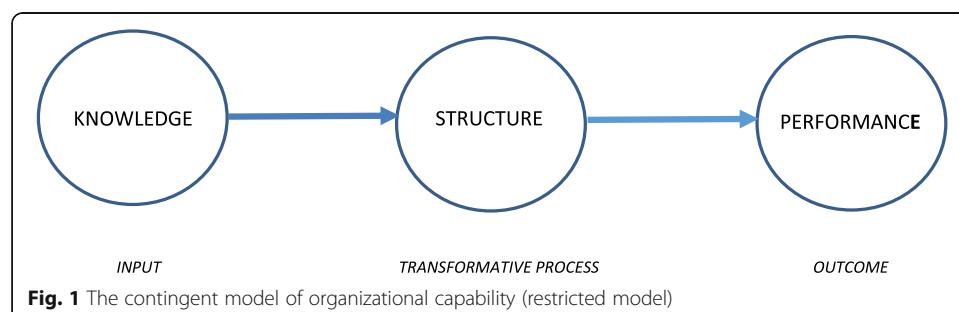
organizational effectiveness). Knowledge application triggers the choice of the best organizational structure, which in turn serves to coordinate cognitive activities that generate performance outcomes. Organizational structure here represents an activity *pattern* (or a recursive cycle of how processes are conducted in time) that generates the performance space for a particular firm. Organizational capability is the emergent result of the dynamic fit between these IPO elements.[1]

The model defines a problem from the perspective of the content knowledge that is required to solve it. Problem difficulty is an important dimension, and it is defined by the amount of knowledge required to resolve it in given historical context (e.g., based on the stage of scientific development). Increasing degrees of difficulty generate the need for increasing *quantities* of knowledge and, consequently, an increased demand for knowledge aggregation and synthesis. As tasks and sub-tasks become increasingly interdependent, there is a corresponding increase in knowledge dedicated to the interconnectivity of tasks. Knowledge of task integration can be measured through increasing levels of *activity dependency*, as originally proposed by Thompson (1967). However, here, we are more interested in describing interdependencies from a cognitive perspective than from a mechanical one, which makes this theory more applicable to post-industrial firms dedicated to professional services than traditional industrial ones dedicated to product manufacturing. In order to combine different pieces of knowledge, a knowledge that goes beyond content knowledge is needed. As previously proposed, we identify it as *connectivity knowledge*. This type of knowledge is exclusively dedicated to regulatory and/or coordinating functions required in the application of knowledge as a resource.

From a logical perspective, connectivity knowledge can be differentiated according to how it orders tasks (i.e., how tasks are *connected* to each other). Internal connections consider how sub-tasks are related to each other, whereas external connections consider how tasks (and their sub-tasks) are related to other different tasks. The model relies on the ability to measure the degree of temporal interdependency of intellectual tasks required to accomplish an objective within recursive cycles or episodes of knowledge application. The greater the degree of knowledge integration required for effectiveness and efficiency, the stronger the need to coordinate the overall process of knowledge application through a well-designed sequence of cooperative work. As the number of task components increase, the probability of success of a string of tasks being organized sequentially or concurrently in time diminishes for every new added component. The role of the organizational structure is to assist in this "assembly" process through the economic allocation of cognitive effort.

The formula below suggests an arithmetic of knowledge application, as follows:

$$\rho^r = \sum_{n=1}^{r} \kappa_n + \sum_{m=1}^{s} \phi_m \tag{1}$$

where *P* refers to a problem with degree of complexity *r*, *K* is content knowledge with *n* distinct nodes up to *r*, and Φ is connectivity knowledge with *m* ties between pieces of content knowledge up to *s*, so that Φ is contained in K*K and s is bounded to r*(r-1)/2. This model can also be represented in a graph *P* = (K, Φ) that consists of a finite

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[1]The direction of the arrows does not necessarily indicate causal relationships, but demands for alignment and fit (for an elaborated notion of fit, see Drazin R and Van de Ven A 1985; Van de Ven and Drazin 1985;).

set K of vertices representing content knowledge and a finite set of pairs of vertices $\Phi = \{(\kappa_1, \kappa_2) \mid \kappa_1, \kappa_2 \in K\}$ representing connectivity knowledge. *P* is *temporally undirected* if the pair (κ_1, κ_2) is the same as the pair (κ_2, κ_1), while *P* is *temporally directed* if the pair (κ_1, κ_2) is different from (κ_2, κ_1), meaning that the temporal order of κ_1 and κ_2 matters for the process of knowledge application. In a mixed graph, either κ_1 antecedes κ_2 or they occur at the same time, although κ_2 cannot antecede κ_1. This is the condition for the existence of causation, which is the requirement for the functionality of knowledge as a problem-solving resource. The use of knowledge allows *P* to be solved through a temporal process. *P* has a temporal path in a graph in which a tuple of *K* $(\kappa_1, \kappa_2, \dots \kappa_r)$ generates the conditions for the effective completion of a performance episode and (κ_n, κ_{n+1}) is contained in Φ for $1 \le n \le r\text{-}1$. The structural length of *P* is the number of pairs of vertices or ties *m* in Φ on the temporal path and it might involve multiple autonomous performance episodes. In non-deterministic paths, the graph might acquire multiple structural configurations.
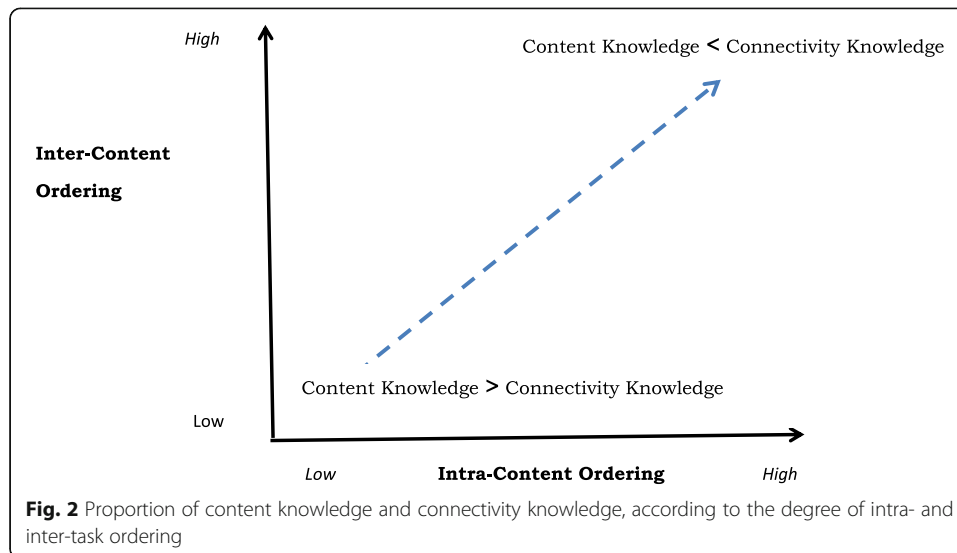
An important feature of Formula 1 is that it indicates that the process of addition of individual pieces of (content) knowledge is not an automatic or simple procedure. It requires an additional knowledge type with the specialized function of connecting (or temporally regulating) different pieces of content knowledge being used as resources of productive tasks. Each one of these two types of knowledge guides tasks in certain ways: The first section of the formula generates *standard tasks*, and the second section generates *meta-tasks*. What is relevant for organizational structure is particularly the ability to conduct the second kind of tasks: When meta-tasks require increasing cognitive effort comparatively to the amount of cognitive effort required by standard tasks, then increasing degrees of structural formalization is subsequently required for operational effectiveness. In this sense, connectivity knowledge underlies a transition function that connects (κ_n, κ_{n+1}) through the mapping $\Gamma(\Phi) : (\kappa_n, I_i) \rightarrow (\kappa_{n+1}, I^*)$, in which I_i informs on the results of the application of κ_n through a task (or set of tasks), generating the conditions for applying κ_{n+1} with an expected result I^*, where the star represents an ideal outcome. A sequence of transformations of this kind requires significant amounts of organized cognitive capabilities proportional to the complexity of the problem being solved.

Figure 2 below illustrates conditions in which the comparative volume of content knowledge and connectivity knowledge changes as the result of the demands for increasing temporal order. Sequential tasks refer to processes of intra-task ordering of content knowledge, while concurrent tasks refer to the process of inter-task ordering of content knowledge. Organizational formalization becomes increasingly relevant when connectivity knowledge becomes comparatively more relevant for problem solving than content knowledge, such that:

Proposition #1: *If the volume of connectivity knowledge is comparatively higher than the volume of content knowledge, then structural formalization should be high.*

Proposition #1A: *A task requiring low amounts of connectivity knowledge (when $\Phi/K < 1$) is better conducted by less formalized organizational structures.*

Proposition #1B: *A task requiring high amounts of connectivity knowledge (when $\Phi/K > 1$) is better conducted by more formalized organizational structures.*

Fig. 2 Proportion of content knowledge and connectivity knowledge, according to the degree of intra- and inter-task ordering

Hypothesis formulation and empirical model

The model advocated in this paper targets firms operating in complex environments, particularly in competitive professional service industries. We have adopted the healthcare delivery sector as a preferred point of reference for model specification and empirical testing. Conducting the analysis through the lens of one exemplary industry facilitates explanation and avoids too much abstraction. In addition, knowledge plays an especially relevant role in industries that are highly dependent on the work of key professionals such as physicians, who plan and conduct treatments based on the use of existing knowledge created in scientific disciplines, such as Medicine, Biology and Pharmacology.

Figure 3 represents the proposition articulated above in a graphic version and recognizes the possibility of hybrid structures. Inter-content ordering requires knowledge for concurrent connectivity, while intra-content ordering requires knowledge for sequential connectivity. When concurrent and sequential forms of connectivity are low, then less formalized organizational structure is sufficient to process the amount of connectivity

Fig. 3 Conversion of connectivity knowledge into organizational structure (with indication of stable structures)
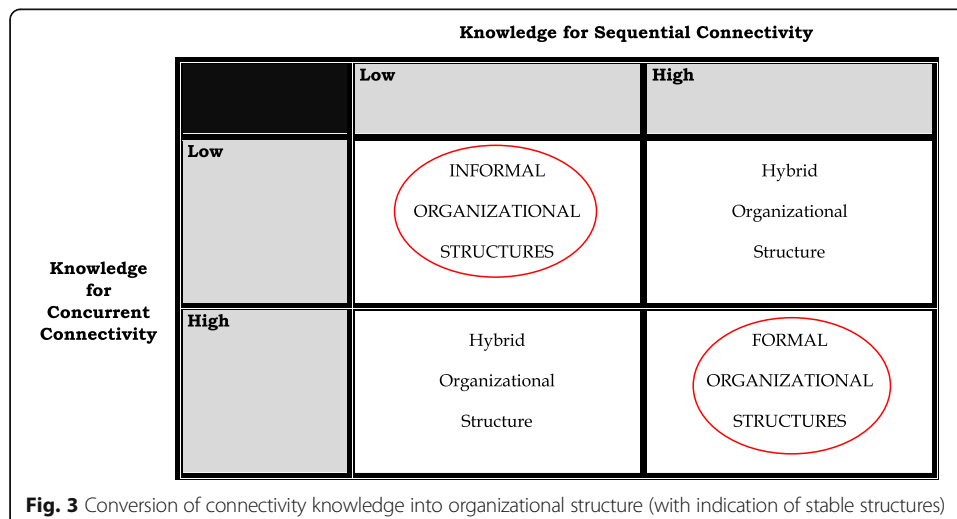
knowledge required for the completion of the job. In other words, there is no need for the organization to formalize procedures; simple common sense based on experience and intelligence from practitioners suffice. When concurrent and sequential forms of connectivity are high, then more formalized organizational structure is needed in order to elaborate the amount of connectivity knowledge required for the completion of the job. In this case, the organization is required to generate more clear decision rules based on articulated policies and procedures. The organization has also to conduct activities related to monitoring and coordination. Translating these propositions to the healthcare sector, we predict a particular relationship between the volume of connectivity knowledge required by therapeutic services and the governance arrangement adopted by the hospital to manage the work of physicians, expressed in the following testable hypothesis:

Core hypothesis: Therapeutic services requiring the application of high volumes of connectivity knowledge will have greater odds of being provided by a more formalized hospital than by a less formalized hospital.

In order to test this hypothesis, we apply a longitudinal logistic regression model on a pilot dataset generated from two annual surveys conducted by the American Hospital Association in 2005 and 2014. The logistic regression technique is used widely in many fields, including the medical and social sciences (Freedman 2009). For example, logistic regression may be used to predict whether a patient has a given disease (e.g., diabetes; coronary heart disease), based on observed characteristics of the patient, such as age, sex, body mass index, results of various blood tests, etc. (Truett et al. 1967). In the present study, this statistical method is used to predict whether the organizational structure of a hospital is related to the connectivity knowledge required to adequately treat patients with certain medical conditions. We assume that the hospital's scope of services is an indication that it has the necessary competence to provide the service to a population of patients.

Hospital's organizational structure is conditioned by the type of contract signed with physicians operating in its premises. These contracts regulating the relationship between hospitals and physicians vary in the degree of formalization of roles and expectations (Scott 1982). In recent decades, various models of hospital-physician relationships have evolved in the USA, and hospitals have begun adopting different organizational options (Robison 1999; Scott et al. 2000). Ways of incorporating physicians into the hospital fall along a broad continuum ranging from loose networks to tightly coupled hierarchies. In addition to the traditional open system model (OSM), the American Hospital Association (AHA 2016) has recently identified eight distinct forms of hospital-physician contracting, including (1) Independent Practice Association (IPA), (2) Group Practice without Walls (GPWW), (3) Open Physician-Hospital Organization (OPHO), (4) Closed Physician-Hospital Organization (CPHO), (5) Management Services Organization (MSO), (6) Integrated Salary Model (ISM), (7) Equity Model (EM), and (8) Foundation Model (FM).

Currently, the most common hospital-physician relationships are governed by OSM, IPA, CPHO, and ISM. OSM and IPA together represent approximately 56% of US hospitals, ISM approximately 29%, CPHO and MSO approximately 8%, and the others

approximately 4% (AHA 2016). These organizational arrangements reflect the level of risk shared by each party, the integration of operations, the degree of exclusivity, and the investment of capital. In the OSM, physicians own their practices and admit patients to one or more hospitals on whose medical staff they serve. The requirements for membership are few, as are the responsibilities (Casalino and Robinson 2003). In the IPA, physicians continue owning their practices but become formally affiliated with a hospital and are motivated to increase compliance with the hospital's management initiatives to decrease costs and increase quality. In CPHO, physicians have some degree of independence, but are constrained by exclusivity contracts and share responsibilities for treatment outcomes through the adoption of standardized business practices, joint planning, and clinical integration (Burns et al. 2000; Cuellar and Gertler 2006). Finally, in the ISM, physicians are employed by the hospital, which purchases both physical and intangible assets as well as requires physicians to operate in centralized locations for the sake of coordination (Morrisey et al. 1996). The literature on the subject (Robison 1999; Casalino and Robinson 2003) suggests that these variations on the hospital-physician relationship correspond to four basic forms of governance described in organizational economics: arm's length, alliance, joint venture, and hierarchy (Williamson 1985).

Similarly to Conner and Prahalad (1996), we focus on basic choices and concentrate on polar organizational modes based on the binary expression of a hospital's degree of formalization between network and hierarchy. This means that our empirical model classifies OSM and IPA as *open networks*, and CPHO and ISM as *closed hierarchies*,[2] which intends to represent and contrast the two polar ends of a structural continuum.[3] As noticed above, these are recurrent configurations and might represent relatively stable models of contracting between hospitals and physicians in the current historical context of the American healthcare service market. In the present stage of theory development, it is preferable to apply simplified methodological approaches and improve precision in future studies. In addition, data provided by the American Hospital Association (AHA) annual surveys is still inadequate for a more precise specification of the current model. For these different reasons, we have decided to apply the *binomial logistic regression* methodology instead of the *ordered logistic regression* one.

Like other forms of regression analysis, the logistic regression makes use of one or more predictor variables that may be either continuous or categorical. However, unlike ordinary linear regression, logistic regression is used for predicting binary-dependent variables rather than a continuous outcome (Hosmer and Lemeshow 2000). In the present case, independent variables are represented in a categorical form, expressed in binary terms (i.e., dummy variables indicating whether a selected therapeutic service is offered or not by a hospital). At this stage of model development—in which knowledge required to conduct particular tasks is not yet fully described in terms of its

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[2]Both of these hospital arrangements are considered decentralized hierarchies because physicians continue to have full control of decision-making regarding the adoption of therapeutic practices, which is consistent with the American law that prohibits the "corporate practice of medicine" (i.e., it is always the physician who makes the ultimate decision, not the hospital) (Robison 1999).

[3]Open networks do not represent informal structures per se, but simply less formal ones compared to those promoted by closed hierarchies. Even when contracts allow the autonomy of individual physicians, they are bound to a series of professional expectations that include the adoption of ethical standards as well as best practices promoted in medical schools and medical professional associations.

composition of content and connectivity knowledge, we take a reasonable methodological shortcut. At this point, we are essentially interested in measuring the probability that therapeutic services (ordered by the comparative magnitude of connectivity to content knowledge) will be offered by an integrated, hierarchical hospital. The ordering of therapeutic services was generated in clusters of medical fields through the comparison of therapeutic services based on their respective configuration of tasks and meta-tasks.

The probability for a certain therapeutic service to be offered by a formalized mechanism of governance varies between 0 and 1. The probability of a service occurring in a formalized hospital is p, and the probability of the same service occurring in a less formalized hospital network is $q = 1 - p$. Odds are defined as the ratio of the probability of success and the probability of failure, such that:

$$\text{odds}_{(formalization)} = p/(1-p) \text{ or } p/q \tag{2}$$

The model can then be fully expressed as follows:

$$\text{logit}(p) = \log(p/1-p) = \beta_0 + \beta_1 T_{(\Phi)} + \beta_2 S_{(\sigma)} + \beta_3 R_{(\delta)} + \varepsilon \tag{3}$$

where p indicates the probability of a formalized hospital to be selected, β_1 are the regression coefficients associated with the selected group of services represented by the independent variable $T_{(\Phi)}$ also expressed in binary terms (i.e., 1 if offered and 0 if not offered). The other independent variables $S_{(\sigma)}$ and $R_{(\delta)}$ are control measures for hospital size and the degree of rivalry in the region, respectively. They serve to isolate other potential relevant sources of influence upon the choice of organizational structure such as organizational complexity and competitive intensity -- and can be understood as other potential relevant contingency factors. The estimated β_1 coefficients produce results in terms of log-odds and then converted to odds ratios, as explained in the empirical section below.

Empirical testing

We tested the hypothesis in a model considering 15 (fifteen) therapeutic services, three for each one of these core medical areas of specialization: cardiology, oncology, orthopedics, gastroenterology, and central nervous system. Hospitals are usually compared to each other based on these traditional services (e.g., *US News and World Report*'s hospital rankings). Each one of them were assessed and classified with the purpose of ranking each procedure according to the estimated amount of connectivity knowledge they require for effectiveness. The purpose was simply to order services in relation to each other, which is the first step of creating a systematic arithmetic of knowledge application. Given that there are three services considered for each medical area, they were labeled as *low*, *medium*, and *high* based on the amount of connectivity knowledge they require (see Fig. 4 below).

The assessment relied on an exploratory methodology based on the episodic theory of performance effectiveness proposed in Marks et al. (2010). Performance episodes are meaningful periods of time during which members of a team work to achieve shared goals and feedback becomes available. Episodes (or recurrent cycles of performance) depend on three superordinate team process dimensions, including (a) action, (b) transition, and (c) interpersonal stages of performance. Action processes occur during performance episodes and include specific activities for the accomplishment of goals.

Amount of Connectivity Knowledge	Cardiology	Oncology	Orthopedics	Gastroenterology	Central Nervous Syst.
Low ↕ High	I. Catheter Services II. Cardiac Intensive Care III. Cardiac Surgery	I. Chemotherapy Treatment II. Oncology Surgery III. Oncology Services	I. Orthopedics Services II. Trauma Ctr III. Arthritis	I. Colonoscopy II. Surgery Intensive Serv. III. Robotic Surgery Services	I. Neurologic Service II. Psychiatric Services II. Geriatric Services

Fig. 4 Cluster of therapeutic services per medical field ordered according to the volume of connectivity knowledge

Transition processes occur as team cycle from one performance episode to another. During transition phases of performance, team reflects on how they have previously functioned and develops plans for future efforts. Performance episodes also encompass the need to manage interpersonal processes that occur at any time during the team's life cycle and include managing conflicts, motivation, and affect levels (Eddy et al. 2013). The transition stage was used as a proxy for the amount of connectivity knowledge being processed and applied during the performance of a job. The increasing amount of time dedicated to transition stages is an indication of task complexity and uncertainty, which signals the application of large amounts of connectivity knowledge. It is reasonable to assume that the amount of feedback, control, revision, and coordination required by a therapeutic service reflects the amount of (temporal) order required by tasks contained in a job. Treatments were ranked according to the sophistication of transition processes they typically require assuming a certain amount of standardization of practices across hospitals. A more precise specification of the IPO model with different levels of abstraction is suggested by Fig. 5 below.

We also limited the sample of hospitals to only those ones located in a restricted geographic area in order to control for the heterogeneity of external factors and minimize the effects of different degrees of competitive intensity. This means that $R_{(\delta)}$ in Formula #3 is kept fixed. Only hospitals located in New York and New Jersey were considered in the study based on data provided in the 2005 and 2014 *National Hospital Survey* (conducted by the American Hospital Association—AHA). From the approximately 600 hospitals covered by the surveys in both states, we selected a sample of 105 hospitals with a complete or unabiguous set of data and stable scope of services in those selected medical areas, including 57 hospitals in New York and 48 in New Jersey. Approximately 60% of all of them were classified as having less formalized structures (i.e., they operate primarily through a network of physicians) and 40% classified as having more formalized structures (i.e., they operate primary through salaried physicians or exclusivity contracts).[4]

The option to consider hospitals with a fixed scope of services (in those five selected medical fields) within a decade intends to simplify the testing procedure and relies on

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[4]Given that all hospitals are necessarily decentralized in the USA as the result of the illegality of the corporate practice of medicine, it is possible to say that the degree of organizational centralization is also being controlled in this model through the selection of the sample. In this sense, professional organizations can be very different from traditional manufacturing firms.

Fig. 5 The contingent model of organizational capability, decomposed in different levels of abstraction
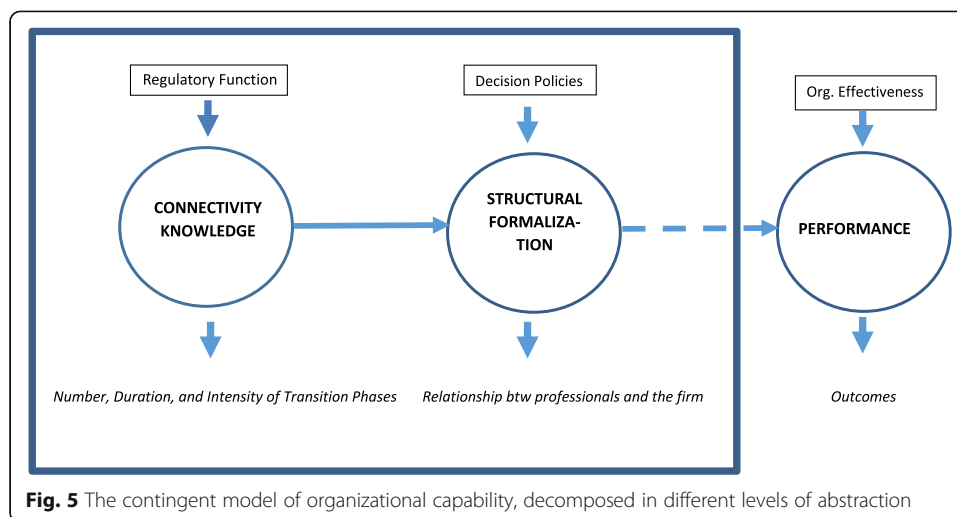
the assumption that changes in core services are costly and infrequent. Hospital's scope reflects previous investment commitments and is likely to persist in time as any other major investment in "sticky" resources (Ghemawat 1991). This methodological approach is also justified on the ground that the objective of the present study is to identify stable relationships. The theoretical model relies on the evolutionary assumption that only the most efficient and effective structural solutions persist in history (Nelson and Winter 1982). Dealing with this kind of sample, however, requires the adoption of special methodological procedures. Standard logistic regression models depend on independent binary outcomes, whereas here the outcomes arise from the dependency of multiple observations per subject (i.e., the same hospitals located in a geographic region for a period of a decade). In this case, the independent variables and the error terms are not independent from each other. This means that the estimated logistic coefficients for therapeutic services are *not* an unbiased measure of true parameters. The estimation of the standard errors needs to deal with this deviation from the standard case and assume that, if the measurement and estimation were repeated, we would observe results in the same range as reported (Stata 2013, pp. 309–310). In addition, we also adopt a correlation structure in which observations are only related to their own past values through a first-order autoregressive (AR-1) process. For these reasons, the logistic regression coefficients are estimated based on the "sandwich" estimator of variance, which is a more robust technique developed independently by Huber (1967) and White Jr. (1980).[5] This procedure reflects the average dependence among the repeated observations over subjects when the data do not come from either a simple random sample or the distribution of independent variables and error terms are not independently and identically distributed (i.i.d.). The resulting estimator for the odds remains consistent given that the variance estimates are based on the weak assumption that the weighted average of the

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[5]This procedure is conducted in STATA 13 through the command *vce*(*robust*) (combined with frequency weights *fw*).

estimated correlation matrices converges to a fixed matrix (Liang and Zeger 1986; Hu et al. 1998).

All 15 procedures are included together in the same model controlled by hospital size (measured by the number of beds). The odds ratio for a unit change in each covariate are reported in Fig. 6 below, which estimates the coefficients β_1 in Formula #3 for each one of the selected procedures (ordered in blocks of three by medical field). Here, coefficients in log-odds units have already been converted to odds ratio in order to facilitate interpretation.[6] The odds ratio for a unit change in each covariate are predicted to grow by the amount of the estimated coefficient. At fixed values of the other covariates, cardiac surgery, for instance, has over two times the odds of being offered by Integrated Salary Model (ISM) than by Open System Model (OSM) hospitals, whereas the odds for catheter procedures and cardiac intensive care are 0.34 and 0.56, respectively. Odds ratios greater than 1 correspond to positive effects because they increase the odds. Those between 0 and 1 correspond to negative effects because they decrease the odds. Odds ratios of exactly 1 correspond to "no association." In this case, both catheter and cardiac intensive care are more likely to be offered by a hospital adopting a less formalized structure. This does not mean that they are not offered by formalized hospitals, only that their likelihood is comparatively lower.

The present study is not particularly concerned with the exact value of coefficients per therapeutic service, but with the comparative ordering of the magnitude of these coefficients within each selected medical area. In the example above, the coefficients for the three services in the cardiology field are ordered according to the predicted classification of the amount of connectivity knowledge, as previously shown in Fig. 4. This means that the result is consistent with the classification that catheter, having the lowest level of connectivity knowledge, will have a lower odds ratio than cardiac surgery, which has the highest level of connectivity knowledge. Cardiac intensive care has an odds ratio with a magnitude in between these two services (although not exactly symmetric), which confirms its classification as having a medium level of connectivity knowledge. Empirical results for the other medical fields largely corroborate the classification specifying the amount of *comparative* connectivity knowledge per therapeutic service. Even in the case of surgical intensive services in which the odds ratio coefficient is not statistically significant, there is an indication that it has a medium level of connectivity knowledge compared to colonoscopy and robotic surgery. When the coefficient is not statistically significant, it indicates a lack of statistical association, meaning that the service is equally likely to be present in both types of hospitals.

The control variable for hospital size is not statistically significant, meaning that the increase of the number of beds offered by a hospital does not affect the degree of structural formalization.[7] The constant is also not statistically significant. The overall logistic model generates a pseudo R^2 of 0.1926, and a Wald chi2 of 236.80 with Prob > chi2 of 0.0000. The log pseudo-likelihood is − 578.93. Combined, these results show a consistent and strong support for the theoretical model, although

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[6]The conversion process followed the tradition of *exponentiating* the original coefficient. This procedure is conducted in STATA 13 through the command *or*.

[7]Regional competitiveness was hold fixed and generate results valid for only high levels of competitiveness among hospitals and medical insurance.

Variables	Odds Ratio	Robust Std. Error	z	P>|Z|	95% Conf. Interval	
Catheter	0.3429	0.1143	-3.210	0.001	0.1784	0.6593
Cardiac Intensive Care	0.5683	0.1056	-3.040	0.002	0.3948	0.8183
Cardiac Surgery	2.6504	0.6092	4.240	0.000	1.6891	4.1589
Colonoscopy	0.6165	0.1483	-2.010	0.044	0.3847	0.9879
Surgery Intensive Svc	1.2463	0.3268	0.840	0.401	0.7454	2.0839
Robot Surgery	1.7754	0.3371	3.020	0.002	1.2238	2.5757
Neurological Svc	0.6012	0.1661	-1.840	0.066	0.3498	1.0333
Psychiatric Svc	1.8453	0.3278	3.450	0.001	1.3027	2.6141
Geriatric Svc	1.8939	0.3153	3.840	0.000	1.3666	2.6247
Chemotherapy	0.5201	0.1544	-2.200	0.028	0.2906	0.9307
Oncology Surgery	1.8254	0.3357	3.270	0.001	1.2731	2.6177
Oncology Svc	1.9235	0.6471	1.940	0.052	0.9948	3.7195
Orthopedics	0.172	0.0639	-4.730	0.000	0.0831	0.3564
Trauma Ctr	2.3478	0.4252	4.710	0.000	1.6461	3.3484
Arthritis Ctr	7.3405	1.8616	7.860	0.000	4.4652	12.0672
Beds	0.9993	0.0003	-1.620	0.104	0.9985	1.0001
Constant	1.3126	0.4461	0.800	0.423	0.6743	2.5551

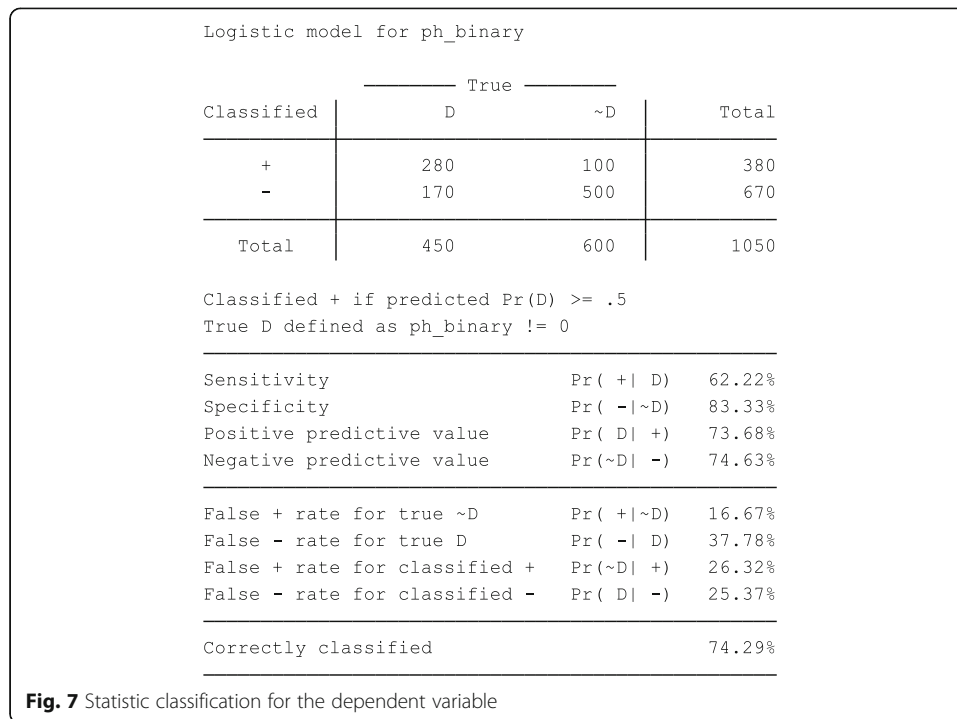|	
Number of Observations	1050
Number of Hospitals	105
Wald Chi2 (16)	236.80
Prob > chi2	0.0000
Pseudo R2	0.1926
Log PseudoLikehood	-578.9398

Fig. 6 Parameter estimates for therapeutic services (ordered by medical areas)

not in a deterministic way. More than 80% of the variance in hospital's choice of degree of formalization is not being explained by the model. This shows that other factors influence organizational structure in the healthcare sector. However, in a complex industry like this one, being able to account for approximately 20% of the behavior of a phenomenon can be considered quite relevant for theory development.

Post-estimation tests corroborate this conclusion by generating strong support for the model. Figure 7 presents the classification statistics and classification table showing that the overall rate of correct classification is estimated to be 74.29%, with 83.33% of the more formalized hospitals correctly classified (specificity) and 62.22% of the less formalized hospitals correctly classified (sensitivity), both groups having probabilities greater than the standard cutoff of 0.5. Figure 8 depicts the ROC curve (which accounts for the *receiver operating characteristics*). This is a graph of sensitivity versus one minus specificity and calculates the area under the curve. A model with no predictive power would be a 45o line. The greater the predictive power, the more bowed the curve, and hence the area beneath the curve is often used as a measure of the predictive power (STATA 2013: pp. 1119–1120). The area under ROC curves generated by the specified model is 0.7744, which is a measure of high predictive power.

Conclusion

Although competition plays a key role in conditioning the performance of organizations, strategic management is increasingly concerned with the impact of organizational capability in a firm's ability to deliver value to end consumers. Competing through capabilities means that organizations have to pay close attention to factors that significantly influence their

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Logistic model for ph_binary

                ————— True —————
Classified  |       D            ~D      |         Total

    +       |      280          100      |           380
    -       |      170          500      |           670

  Total     |      450          600      |          1050

Classified + if predicted Pr(D) >= .5
True D defined as ph_binary != 0

Sensitivity                    Pr( +| D)    62.22%
Specificity                    Pr( -|~D)    83.33%
Positive predictive value      Pr( D| +)    73.68%
Negative predictive value      Pr(~D| -)    74.63%

False + rate for true ~D       Pr( +|~D)    16.67%
False - rate for true D        Pr( -| D)    37.78%
False + rate for classified +  Pr(~D| +)    26.32%
False - rate for classified -  Pr( D| -)    25.37%

Correctly classified                        74.29%
```

Fig. 7 Statistic classification for the dependent variable

long-term sustainability. Organizations that survive and grow in open market systems are usually those capable of applying relevant knowledge to the process of transforming inputs into outputs. Firms are special organizations precisely because they specialize in the process of conducting difficult and complex tasks through the application of knowledge. However, knowledge is not useful unless the organization develops the necessary infrastructure and complementary functions to apply it adequately. The application of knowledge as a productive resource is far from being a trivial procedure. What matters the most in this regard is the firm's ability to align the knowledge required to conduct productive tasks with the

Area under ROC curve = 0.7744

Fig. 8 The ROC curve
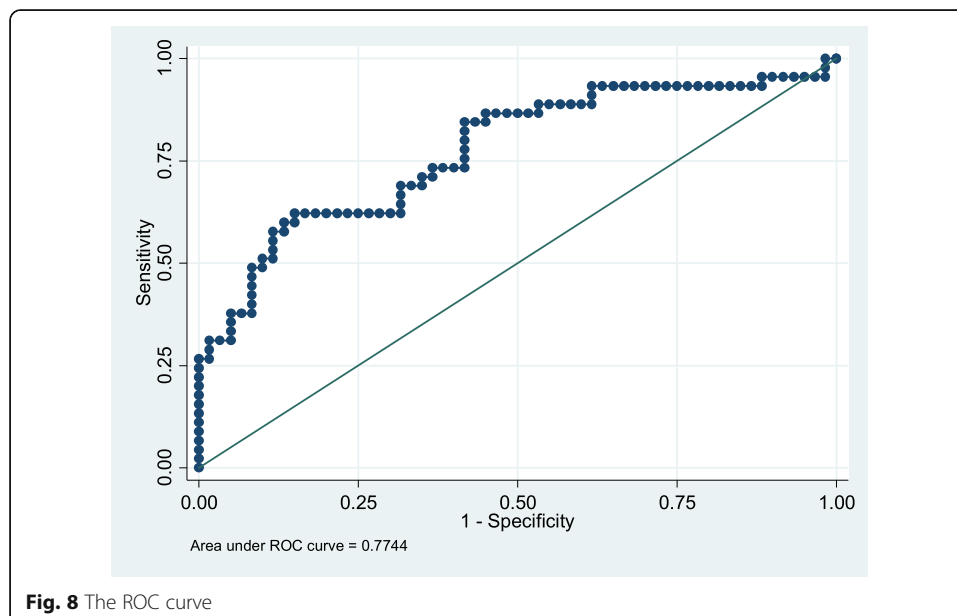
capability of processing it. In other words, the organization depends on the fit between its knowledge function and its governing structure. A contingency perspective of the organizational capability theory of the firm promises to find the right match between them.

Not all types of knowledge affect organizational form equally. Only that portion of knowledge dedicated to regulating multi-task jobs ultimately affects how the firm is internally structured. This point is extremely important because previous contingency models treated knowledge as a homogenous resource from a functional perspective. However, it is clear that knowledge can have different productive functions, including the ability to integrate different pieces of knowledge through organized cognitive work. This type of knowledge is used to *temporally order* content knowledge, which has relevant implications for the choice of governance structures, in particular those features of the structure concerned with the formalization of work processes. Increasing volumes of knowledge dedicated to regulating tasks (i.e., knowledge applied to meta-tasks) demand the adoption of coordination procedures expressed through the clear articulation of decision-making standards. The contingency perspective informs the firm on how to best design the features of the organizational architecture: less formalized structures should be adopted when the volume of connectivity knowledge is relatively low, while more formalized structures should be adopted when the volume of connectivity knowledge is relatively high.

The empirical evidence seems to support the theoretical relationship between connectivity knowledge and the degree of organizational formalization, although not necessarily in deterministic ways: the model was capable of explaining 19% of the variability in organizational forms adopted by hospitals located in a particular geographic location of the USA. This region is highly competitive and demonstrates how imperative it is for hospitals to make the right investments in the long-term scope of therapeutic services. The empirical findings generated by this study are not conclusive but support the emergence of a contingency theory of organizational capability. Future studies will need to fill the existing empirical gap based on improved classification of jobs according to their dimensions of tasks and meta-tasks. Instead of a comparison based on a simple ordinal classification, as done here, the next phase in this research program will require a much more precise description and measurement of each therapeutic procedure. For simplification reasons, the present study assumed that medical treatments are homogeneous across hospitals within the same geographic region, which might not accurately reflect the actual variability of practices. We have not yet achieved this stage of analytical precision due to limitations in the availability of appropriate databases. Much work still needs to be done in order to make a conclusive judgment of the validity of the suggested theory. The conceptual model, nevertheless, has passed a first and relevant attempt at falsification, which is important to motivate additional studies on this particular direction, not only in the healthcare industry but also in other industrial sectors highly dependent on the application of connectivity knowledge for the delivery of value to end consumers.

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