Hierarchy, Team Familiarity, and Capability Development: Evidence from Indian Software Services

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ABSTRACT

What is the source of organizational capabilities? This paper examines one potential source bringing together conceptual streams from strategy and organizational theory on the determinants of learning to examine how *team familiarity* (i.e., previous shared work experience) influences the development and effectiveness of organizational capabilities. I explore the separate effects of *hierarchical team familiarity* (a manager's experience with front-line team members) and *horizontal team familiarity* (front-line team members' experience with one another) on team performance. I also consider whether these distinct measures of team familiarity moderate the relationship between project complexity and team performance. Using data on all software development projects completed over a three-year period at a large Indian firm in the global outsourced software services industry, I find that hierarchical team familiarity is positively related to a project's being on budget and on schedule, while horizontal team familiarity is positively related to the quality of a project's overall performance. With respect to budget and schedule performance, I also show that hierarchical team familiarity moderates the impact on performance of a project's complexity. This study's empirical analysis demonstrates that organizational capabilities grow through the development and strengthening of ties between organizational actors.

INTRODUCTION

Are organizational capabilities simply the aggregation of individual skills and experience, or do they also depend on particular connections between individuals developed through *prior* work experience? While the strategy literature widely recognizes that organizational capabilities[1] can lead to a competitive advantage (Barney, 1986; Hayes, Wheelwright, and Clark, 1988; Nelson and Winter, 1982; Peteraf, 1993; Wernerfelt, 1984), less is known about the microfoundations of these capabilities (Helfat, 2000; Helfat and Lieberman, 2002; Spender and Grant, 1996). If a capability consists of the accumulated knowledge of an organization and its members (Dosi, Nelson, and Winter, 2000; Nelson and Winter, 1982; Pisano, 1997), then any experience offering new and valuable knowledge may contribute to the evolution of a capability. This suggests that experience gained from repeated interactions between defined sets of people in an organization may be important to capability development and effectiveness (c.f. Hayes, Pisano, and Upton,

[1]Winter (2000) defines a capability as "a high-level routine (or collection of routines) that, together with its implementing input flows, confers upon an organization's management a set of decision options for producing significant outputs of a particular type (p. 983)."

1996). As noted by Argote and Ingram (2000), however, these potentially vital interactions have seldom been examined in this light (see also, Argote, McEvily, and Reagans, 2003; Felin and Foss, 2005). This paper explores how *team familiarity* (i.e., previous shared work experience) influences the development and effectiveness of capabilities at Wipro Technologies, a large Indian organization competing in the global outsourced software services industry.

Before empirical study of an organizational capability's development is possible, a valuable organizational capability must first be isolated. In their study of another Indian software services company,[2] Ethiraj et al. (2005) identified an important capability—project management—and showed it correlates positively with project profitability. The project management capability involves coordination of problem-solving activities and its effectiveness is measured as the ability to deliver a project on budget, on time, and with appropriate quality. Here I bring together conceptual streams from strategy and organizational theory on the determinants of learning to explore how the experience of individual team members working together affects the performance of each facet of the project management capability. I examine the separate effects of *hierarchical team familiarity* (a manager's prior work experience with front-line members on a team) and *horizontal team familiarity* (front-line team members' previous work experience with one another) on project team performance. This question is important as prior work on team familiarity has not distinguished between the hierarchical roles that individuals hold inside teams; rather, the work has treated interactions across roles as equivalent. Due to differences in factors such as decision rights (Jensen and Meckling, 1976) and situated knowledge (Tyre and von Hippel, 1997), the impact of prior shared experience on capability development and effectiveness may differ based on individuals' roles.

[2] The setting for Ethiraj et al.'s (2005) work is a Top Five firm in the industry, although the name is not disclosed. While the company I study is also one of the five largest companies in the industry according to most metrics (employees, revenue, etc.), managers at this company have stated they were not the site for the Ethiraj et al. study.

Having examined whether hierarchical and horizontal team familiarity have average effects on performance, I next turn to whether these two types of team familiarity are more beneficial as tasks grow in complexity (Argote, 1993; Espinosa *et al.*, 2007). Increasing team familiarity is but one way to develop capabilities. An alternative approach involves the explicit codification of process knowledge (March and Simon, 1993; Winter, 1987; Zollo and Winter, 2002). For example, an organization could invest resources to create a detailed process map outlining the work to be completed and communication pathways for individuals. By codifying knowledge about the routine or process, an organization might alleviate the need for the more tacit knowledge that arises from team familiarity. However, new contingencies may arise while work is being completed – for example, due to increased work complexity. Increasing complexity may complicate both the prediction of new tasks (Sommer and Loch, 2004) and management of the increasing number of interrelated tasks due to bounded rationality (Simon, 1947). In other words, as coordinating activities through the codification of knowledge becomes more challenging, team familiarity may grow more vital to successful performance. I therefore empirically examine whether hierarchical and horizontal team familiarity moderate the relationship between complexity and performance.

As part of my theory-building process I conducted significant field research at Wipro, interviewing over 90 individuals from the chairman to project engineers. I also performed over 30 interviews with industry experts and other leading Indian and multinational competitors. My time at Wipro enabled me to gain access to unique internal data, including characteristics and performance measures for 1,137 projects completed over three years, as well as detailed individual-level experience information about the 12,709 individuals who took part in these projects. The combination of objective project performance information and experience data on all team members (as opposed to just team leaders) permits me to examine how individuals' prior interactions across and between hierarchical levels affects capability performance.

This study's empirical analysis determines that hierarchical team familiarity is positively related to a project's being on budget and on schedule, while horizontal team familiarity is positively related to the quality of a project's overall performance. With respect to budget and schedule performance, this study also shows that hierarchical team familiarity moderates the impact on performance of a project's complexity. In robustness checks, I find no evidence that selection bias is the primary reason behind these results. My findings show that capabilities depend, in part, on connections between individuals developed through prior work experience (Helfat and Peteraf, 2003; Peteraf, 1993), and that theory on team familiarity needs to account for role relationships within teams. Finally, my results suggest that the type of familiarity most important to an organization may depend on the organization's strategy and objectives.

KNOWLEDGE, EXPERIENCE AND OPERATIONAL CAPABILITIES

The concept of an organizational capability—the "generally reliable capacity to bring that thing about as a result of intended action" (Dosi *et al.*, 2000: 2) —has proven to be a valuable construct for examining the linkage between organizational action and performance (e.g. Henderson and Cockburn, 1994; Nelson and Winter, 1982). While capabilities play a key role in developing and sustaining a competitive advantage (Barney, 1986; Peteraf, 1993; Winter, 1995), capabilities are not distributed exogenously to organizations, but rather are built over time (Dierickx and Cool, 1989; Gavetti, Levinthal, and Ocasio, 2007). Despite apparently similar resource allocations, subsequent performance along many different measures can vary dramatically based on an organization's capabilities (Chew, Bresnahan, and Clark, 1990; Nelson, 1991). Prior work has divided capabilities between those that are operational (i.e., deliver current performance, Winter, 2003), and ones that are dynamic (i.e., involve changing existing firm activities, Teece, Pisano, and Shuen, 1997). In this study I focus on operational capabilities.

A common criticism of research on capabilities is that the generality of this construct invites ambiguity and permits scholars to ignore the question of how capabilities are developed and executed (Collis, 1994; Felin and Foss, 2005; Priem and Butler, 2001; Williamson, 1999). As a result, as empirical studies have shown that organizational capabilities lead to improved performance (e.g. Henderson and Cockburn, 1994; King and Tucci, 2002; McGahan and Porter, 2002), attention has shifted to understanding how capabilities are developed in practice (Helfat, 2000; Iansiti and Khanna, 1995; Narduzzo, Rocco, and Warglien, 2001). Since a capability consists of the accumulated knowledge of an organization and its members (Dosi *et al.*, 2000; Kogut and Zander, 1992; Nelson and Winter, 1982; Pisano, 1997), investigating the building of capabilities involves studying this underlying knowledge.

Prior work has noted that organizational capabilities include two types of routines: (1) routines for completing individual tasks and (2) routines to coordinate the completion of these tasks (Helfat and Peteraf, 2003). To examine the microfoundations of capabilities then requires not only examining the individuals involved in task completion, but also how their interactions affect the coordination of tasks (Argote and Ingram, 2000; Hayes *et al.*, 1996; Simon, 1991). I therefore study how team familiarity, i.e., individuals' prior shared work experience with team members, may improve performance and lead to the development of organizational capabilities.

The Relationship between Team Familiarity and Performance

The first question I consider is why previous experience with the *same* team members (i.e., team familiarity) may improve performance, as compared to a group of individuals with the same amount of task experience accumulated with different team members. Team members who repeatedly collaborate with one another may develop social capital and improve their ability to coordinate actions (Adler and Kwon, 2002; Chillemi and Gui, 1997; Goodman and Leyden, 1991). With recurring interactions team members build rapport and so avoid the process losses that occur when groups are newly formed (Harrison *et al.*, 2003; Steiner, 1972). However, too much team familiarity may be detrimental to performance as Katz (1982) found a negative second-order effect (Berman, Down, and Hill, 2002; Kim, 1997). Since, it took over five years in Katz's study for the negative effect to appear, teams in existence for only months, as opposed to years, may be less likely to suffer from this effect (Huckman, Staats, and Upton, 2008). More generally, the benefits of team familiarity can be grouped into three categories: locating knowledge, sharing knowledge, and applying knowledge.

Before teams can use new knowledge, they must first *locate* it (Haas and Cummings, 2008; Monteiro, Arvidsson, and Birkinshaw, 2008). Individuals have mixed success recognizing valuable knowledge within a group (Littlepage, Robison, and Reddington, 1997). A Transactive Memory System (TMS) is one way a team can increase their likelihood of accomplishing this task (Wegner, 1987). As team members work together, they enact a TMS that includes a representation of who knows what (Lewis, 2003; Moreland and Myaskovsky, 2000). This enables the "encoding, storing, retrieving, and communicating [of] group knowledge." (Lewis, Lange, and Gillis, 2005: 581) Whether through a TMS or another way, by knowing who knows what, team members can coordinate activities more successfully (Kogut and Zander, 1992; Moreland, Argote, and Krishnan, 1998).

Even if knowledge is located, it must still be *shared* between the sender and receiver (Teece, 1981). Szulanski (1996) finds that it is not a lack of motivation, but rather "knowledge-related factors" that are the primary variables explaining why knowledge is not shared successfully inside organizations. Working with the same team members may increase the quantity and quality of knowledge sharing (Monteverde, 1995; von Hippel, 1994). Members' recurring interactions help the team to establish communication channels and a common language (Arrow, 1974; Lazear, 1999; Weber and Camerer, 2003). As team members share experiences, they may build trust, yielding performance benefits (Granovetter, 1985; McEvily, Perrone, and Zaheer, 2003; Uzzi, 1997). Team beliefs, about positive social acceptance or team psychological safety, may be created which can enable learning and improve performance (Edmondson, 1999; Gruenfeld *et al.*, 1996; Hinds *et al.*, 2000). In psychologically safe environments, team members may be more likely to share their mistakes and take risks, resulting in more experimentation and more innovative thinking (Edmondson, 1996; Lee *et al.*, 2004).

Finally, team familiarity helps with not only locating and sharing knowledge, but also *applying* it. Experience working together may help managers allocate tasks more effectively and also help team members coordinate across specialized roles (Liang, Moreland, and Argote, 1995; Reagans, Argote, and Brooks, 2005; Reagans, Argote, and Spektor, 2008). As team members share experiences they may develop team mental models that depict the knowledge that is common to team members (Kozlowski and Ilgen, 2006). Shared mental models may improve performance through the effective application of relevant knowledge (Mathieu *et al.*, 2000; Mohammed and Dumville, 2001). Team members sharing knowledge may combine it in new ways or find higher order abstractions, creating new knowledge (Wegner, Giuliano, and Hertel, 1985). Thus, team familiarity may enable the creation of a learning system that facilitates the ongoing application of new knowledge (Lewis *et al.*, 2005). Finally, shared experiences may increase team members' willingness to act on useful knowledge from others (Gruenfeld, Martorana, and Fan, 2000; Kane, Argote, and Levine, 2005).

Organizational Hierarchy and Team Familiarity

Scholars in a number of fields have long studied the differing roles and activities of managers and workers (e.g. Marx and Engels, 2002; Taylor, 1911). For example, managers and workers may differ in motivation (Jensen and Meckling, 1976) or experience (Huckman *et al.*, 2008), impacting performance. Despite the generally recognized importance of studying different roles, prior work on team familiarity has not differentiated between the hierarchical roles that individuals have within a team; rather, the work has treated interactions across roles as equivalent. The differences may prove particularly important, however, when examining capability development (Gavetti, 2005; March and Simon, 1993). For example, when individuals interact across hierarchical levels, their situated knowledge (Tyre and von Hippel, 1997) and decision rights (Jensen and Meckling, 1976) are likely to impact their perceptions of conditions and thus their actions (Burgelman, 1983; Ocasio, 1997; Tripsas and Gavetti, 2000).

Most project teams at Wipro are structured to include three levels: project manager, middle manager, and project engineer. The project manager (PM) has full operational control of the team and project engineers execute the work, while middle managers serve a coordination role, interfacing with the project manager and assisting with work completion. This basic hierarchical team structure is common across many settings. To evaluate whether the interaction of individuals within certain role relationships differentially shape capability development I next examine how hierarchical team familiarity (in this case, prior experience between project managers and project engineers) and horizontal team familiarity (i.e., prior experience between project engineers) affect performance.[3]

[3]Since I am interested in exploring the impact of project manager–project engineer experience and project engineer–project engineer experience on performance, here I do not hypothesize about the project manager–middle manager dyad. Since middle managers have an integrative role (they both manage and write code), *ex ante*, it is unclear in

Hierarchical Team Familiarity: Project Managers and Project Engineers

A team may benefit in many ways when a manager and team members have prior shared work experience. For example, through repeated interactions with engineers, a project manager is able to locate team members' relevant knowledge. Having observed the engineers previously, a project manager may know the complexity of work that an individual can handle as well as the engineer's likelihood of completing work on time. Such information facilitates work allocation.

With repeated interactions, the project manager and engineers may build rapport, resulting in a higher comfort level and therefore more sharing of information. This information could be of limited value to a project manager, however, if she is unable to apply it to improve performance. For example, Brooks' Law, a well known axiom in software engineering, states that adding manpower to a late project makes it later (Brooks, 1975). To combat this problem, Wipro has developed many tools and practices to help project managers effectively manage projects (Staats and Upton, 2007). For example, its project management system (developed in-house) enables managers to track schedule and effort performance relative to plan nearly continuously. By providing data and also training project managers to incorporate data into their decision-making, the company adds rigor to a process that is often considered an art (Beck and Boehm, 2003). This foundation allows project managers to benefit from prior shared work experience. If engineers bring an issue to a manager, the manager is able to make changes in response. Also, once a project manager learns of a problem from either an engineer or the system, she can use her prior knowledge of the engineers to assign new work effectively.

Prior work highlights ways that a manager's decisions shape the development of capabilities (Adner and Helfat, 2003; Helfat and Peteraf, 2003). When project managers have

which group to place them. All results reported here hold if I also estimate coefficients for project manager–middle manager and middle manager–project engineer team familiarity.

experience working with project engineers they gain knowledge that may permit them to make higher quality decisions (e.g. in work allocation). This study's first hypothesis is therefore:

HYPOTHESIS 1.	*Hierarchical team familiarity is positively related to team operational performance.*

Horizontal Team Familiarity: Project Engineers with One Another

While horizontal team familiarity (project engineers' previous work experience with one another) provides many benefits discussed previously, there are two structural differences: (1) no one in this group has operational authority for the project and (2) engineers are closer to the work that makes up frontline tasks (e.g., writing the code). Although the lack of formal authority means these individuals do not have complete discretion to respond to obtained knowledge as they see fit (cf. Bower, 1970; Burgelman, 1983), the second point may be particularly important to the development of operational capabilities. Since engineers frequently work together on tasks they may have a more realistic view of the problems at hand (Tripsas and Gavetti, 2000).

For example, the project manager on a software project is not typically involved in writing code, so when a problem occurs, she may misinterpret its severity based on her past experience rather than on the prevailing situation. However, since project engineers are actively engaged in working on the code itself, they may be more likely to understand interdependencies and the specific context. As there are many ways to develop software and it is often difficult to measure performance in-process, engineers who have experience working with one another may be more likely to coordinate their activities successfully. Prior experience may help engineers both to resolve particular problems in the code as well as in the development of informal-advice seeking networks (Leonardi, 2007). While engineers lack formal organizational power, they can exert significant informal influence on project activities (cf. Barker, 1993). Together these strands suggest the following, second, hypothesis:

HYPOTHESIS 2.	*Horizontal team familiarity is positively related to team operational performance.*

Complexity and Familiarity

Having examined whether hierarchical and horizontal team familiarity have average effects on performance, I next turn to whether these two types of team familiarity are more beneficial as tasks grow in complexity (Argote, 1993; Espinosa *et al.*, 2007). This line of thinking is grounded in a more fundamental discussion of how organizations coordinate their actions (e.g., the coordination of problem-solving activities in the case of the project management capability this study examines). If the organization's objective is to facilitate coordination, then team familiarity is just one way to accomplish this goal. Alternatively, organizations regularly invest resources in creating detailed process maps to identify contingencies and the appropriate response to each (March and Simon, 1993; Winter, 1987; Zollo and Winter, 2002).

Due to the cognitive limits resulting from bounded rationality (Simon, 1947), members of organizations create and remember processes and routines so they do not have to constantly generate new responses to the same stimuli (March and Simon, 1993; Nelson and Winter, 1982). Thus, by codifying knowledge about a routine or process, an organization might alleviate the need for knowledge available as a result of team familiarity. However, as work grows more complex, new contingencies arise and each necessary eventuality becomes more difficult to pre-specify—both in terms of predicting unforeseen events (Sommer and Loch, 2004) and managing the increasing number of contingencies. Therefore, as codifying knowledge and using a process map to coordinate activities become more challenging, team familiarity may grow even more important. For example, Espinosa et al. (2007) find that team familiarity moderates the negative impact of team size on speed to completion in the development of a telecom software product. Here I am interested in the impact of hierarchical and horizontal team familiarity on the relationship of project complexity and performance, controlling for other relevant team and project characteristics, leading to the following two-part hypothesis:

HYPOTHESIS 3A.	***Hierarchical*** *team familiarity moderates the relationship between project complexity and team performance.*
HYPOTHESIS 3B.	***Horizontal*** *team familiarity moderates the relationship between project complexity and team performance.*

SETTING, DATA, AND EMPIRICAL STRATEGY

The company under study for this research, Wipro Technologies, is a global provider of software services headquartered in Bangalore, India.[4] The Indian IT-enabled services industry grew from $8 billion in 2001 to $30 billion in 2006: a compound annual growth rate of 31% (NASSCOM, 2008). Wipro offers a wide array of technology-enabled business solutions, such as application development and R&D services. As of December 31, 2006, Wipro had annualized revenues greater than three billion dollars and employed more than 66,000 people worldwide.

In the empirical analyses following, I examine software development projects. Organizations often struggle with the complex and uncertain activities of development projects and are often unable to learn from their experience (Boh, Slaughter, and Espinosa, 2007; Wastell, 1999). The Standish Group reports that in 2004, only 35% of IT projects were successful while 19% were outright failures and 46% were challenged (i.e., the project exceeded its cost or time estimate or did not completely meet a customer's needs (Hartmann, 2006)). A study by Tata Consultancy Services found that 62% of projects missed their schedule estimates and 49% exceeded the cost estimate (TCS, 2007). As teams design solutions, write software code to meet specifications, and then test and implement the solutions, they have to manage the coordination of team activities as well as coordination with customer actions and systems (Faraj and Sproull,

[4] See Arora et al. (2001) and Athreye (2005) for detailed overviews of the Indian software services industry.

2000; Gopal *et al.*, 2003; Krishnan, 1998). Focusing on development projects provides both objective performance measures and controls that permit comparison across projects.

Data

The data analyzed begin with all 1,137 development projects completed at Wipro between January 2004 and December 2006. In addition to the project data, I have compiled complete human capital information on the 12,709 employees who worked on these projects. Typically, individuals work on one project at a time. I also have historical individual data detailing all individual project assignments since 2000 (these data do not include project outcome information). I construct individual employee work histories to capture, over time, an individual's experience with other team members. To build the sample for analysis, I remove projects missing data[5] and those projects with fewer than two project engineers[6], yielding a final sample of 638 projects. Thus, the final sample consists of all software development projects completed at Wipro over the three year period that use kilolines of code as their unit of measurement. An examination of observable information for projects missing data as compared to those without missing data reveals no substantial differences in the variables of interest.

Wipro uses robust processes for data recording and tracking. The company was first in the world to be certified at Level 5 for the Capability Maturity Model Integrated Version 1.1 (SEI, 2001; Wipro, 2008). The quality processes compliant to Level 5 status, including the precise tracking of operational performance, are automated through the internally developed project management tool, *E cube*, thereby enabling consistency of practices. Project managers

[5] Of the removed projects, 468 are missing kilolines of code (KLOC). Not all projects use KLOC as their unit of measurement, and not all projects include coding, so do not have KLOC and thus are excluded from the analysis. An additional twenty projects are missing one of the other variables of interest.
[6] To examine horizontal and hierarchical team familiarity I must have at least one project manager and two project engineers (i.e., three team members) in order for each measure to be meaningful. Since all projects have a PM, only the number of project engineers is a binding constraint.

use *E cube* to submit regular reports, while all execution personnel use the tool to record their project assignments each week. Reports go through a demanding quality assurance process and are subject to random audits by Software Engineering Process Group (SEPG) personnel. I extract additional employee project assignment, role, and demographic information from the company's multiple human resource systems.

Dependent Variables

My dependent variables are the three components of the project management capability (Ethiraj *et al.*, 2005): effort adherence, schedule adherence, and quality performance. Table 1 provides summary statistics for the dependent, independent, and control variables.

***************************INSERT TABLE 1 HERE***************************

Effort and Schedule Adherence. To measure a project's *effort adherence* and *schedule adherence,* I use variables set to one if a project meets or exceeds the respective estimate, and zero otherwise. I use dichotomous variables to capture the fact that the most attention (of the project manager, her manager(s), and the customer) is paid to whether a project delivers as expected. During an interview, a project manager commented, "The target is what we're really looking at. My job is to make sure that there isn't slippage [in schedule] or overrun [in effort]."

Sales personnel at Wipro are responsible for creating the initial effort and schedule estimates. Over the course of a project, both estimates may be altered—typically due to a customer's change in project scope. To revise an estimate, the project manager must obtain the customer's agreement. Subsequently, Wipro business finance and quality managers must also approve the request. This process is designed to ensure that project managers do not alter project estimates simply because a project is not performing to expectations. For my analyses, I use the revised estimates since they most accurately encompass the project's ultimate goals.

Quality. In many but not all development projects, the final step is customer acceptance testing: Wipro gives the finished code to the customer and it is tested against the project's pre-specified metrics. The testing yields a count of the number of defects, and is done by either the customer or the customer's designate so a project team cannot manipulate the test results. When zero defects are recorded, SEPG personnel confirm that testing was undertaken. Customer acceptance testing is a commonly used metric in the field of software engineering (Boehm, 1981), measuring the conformance quality of a project (Garvin, 1987). Thus, to evaluate the quality performance of a project, I use *post-delivery defects*: a count of the defects found in testing.

Independent Variables

Team familiarity. To calculate *overall team familiarity*, I count the number of prior projects that each pair of individuals on a team has worked on together over the past three years. I then sum these values across all unique pairings on the team and divide by the number of possible unique pairs – $N(N-1)/2$ – where N is team size (Reagans *et al.*, 2005). The three-year period captures the fact that, as with learning (Argote, Beckman, and Epple, 1990; Benkard, 2000; Thompson, 2007), team familiarity may decay over time. Also, the three-year cutoff permits observation of several project cycles, as the average project lasts six months.[7]

I also calculate *hierarchical team familiarity* (i.e., project managers and project engineers) and *horizontal team familiarity* (i.e., project engineers with one another). To calculate hierarchical team familiarity, I count the number of prior projects that a project manager has executed with each project engineer on the team over the prior three years, and then divide by the number of non-middle manager team members minus one. For projects with more than one manager, I average the value across project managers (and also count project managers'

[7]By conducting sensitivity analyses with two- and four-year windows, I obtain the same pattern of results.

prior projects with each other). To compute horizontal team familiarity, I remove project and middle managers, then follow the same process as for overall team familiarity.

Project complexity. Simon (1962) defines a complex system as a system "made up of a large number of parts that interact in a nonsimple way (p. 486)." To measure the complexity of a development project, I use the kilolines of new source code (KLOC). While the metric has many shortcomings, it is the measure most commonly used for complexity in software engineering (Boehm, 1981; Scacchi, 1995). As the number of lines of code in a project grows, complexity rises due to both the increasing size of the code base and the multiplying number of potential interactions between the different parts of the code. Since software exhibits scale effects (Banker and Kemerer, 1989), I use the log of KLOC in the analyses. Given that different software languages require varying lines of code to develop similar functionality, I also include indicator variables for the classes of language that appear in the data (Low and Jeffery, 1990).[8]

In the analysis, my focus is not on the main effect of project complexity, but rather its interaction with team familiarity. Thus, I construct the interaction of each measure of team familiarity and project complexity. To aid in the explanation of interaction terms in the nonlinear models, as well as to avoid problems associated with the collinearity of the independent variables, I standardize all continuous variables by subtracting the mean from each and then dividing by the standard deviation. In addition, given the difficulty of interpreting interaction effects from logistic regression models, I repeat the analyses using a linear probability model, and generate the same pattern of results (Hoetker, 2007).

Control Variables

In addition to the variables discussed, I control for other factors that affect performance:

[8] C, C++, Java, query (e.g., SQL), markup (e.g., HTML), BASIC, and Other is the 'excluded' category.

Contract type. Development contracts at Wipro are either fixed price (FPP) or time and materials (T&M) (Banerjee and Duflo, 2000). For a FPP, Wipro and the customer agree to the requirements and a set payment. In a T&M contract, the customer pays a negotiated rate for hours worked on the project. To capture this distinction, I use an indicator variable, *fixed price contract*, which equals one if a contract is FPP or zero if the contract is T&M.

Offshore. Work is typically completed both "offshore" in Wipro's facilities, and onsite at a customer's location. To control for any efficiency or coordination differences from distributing team members across multiple sites (Metiu, 2006; O'Leary and Cummings, 2007), I calculate a variable, *offshore*, measuring the percentage of a project's total hours completed offshore.

Effort. Projects with higher effort (more total hours of work) may be more difficult to manage and thus result in worse operational performance. To control for this effect, I include the log of estimated total person-hours.[9] I use the estimated value because, *ceteris paribus*, a project that misses its estimates would have a higher effort value than one than adheres to its estimates.

Team size. At low levels, increases in team size may improve performance as new team members increase the capacity and knowledge of the unit (Hackman, 2002). However, if a team becomes too large, performance may suffer as coordination problems mount (Brooks, 1975). To measure team size, I use the log of the total number of individuals who took part in the project.

Project duration. Projects that last longer may be more complex or risk disproportionate employee attrition (Ethiraj *et al.*, 2005). As with the effort variable above, there is a potential endogeneity concern, so I measure duration as the log of the estimated project length (in days).

Role experience. I wish to control for the baseline experience of the team. Prior work has shown that role experience (the amount of time each individual has spent in her hierarchical role) is an appropriate measure of team experience in this context (Huckman *et al.*, 2008). I calculate

[9] To account for outliers, I log effort, team size, and duration. Key results do not change with unlogged variables.

role experience by identifying when an individual first assumes the role she holds on a project and using this value to determine the time (in years) that have passed prior to the project start date. I construct the team value by weighting each person's value according to the number of days she was on the project and averaging across team members.[10]

Start year. To control for changing internal and external conditions at the firm level, I include indicators for the year in which a given project started.

Architect. Sixteen percent of projects have a technical architect. Projects with architects are slightly larger than those projects without architects. To account for any unobserved differences, I include an indicator set to one if a project has an architect and zero otherwise.

Software Languages. Some development projects (33% in the data) require more than one software language to meet their objectives. Since a project with multiple languages may be more difficult to complete than one the same size with only one language, I include an indicator set to one if a project includes more than one language and zero otherwise.

Technologies. Finally, in *E cube*, Wipro notes the number of technologies that a project encompasses (e.g. client server, e-commerce, etc.). I set an indicator to one if a project addresses more than one technology, and zero otherwise (93% and 7% of projects, respectively).

Empirical Strategy

I use a conditional logistic regression model for effort and schedule adherence, as I wish to control for time-invariant characteristics of customers that may impact performance (Greene, 2003).[11] To account for any correlation of errors within the projects for a customer I also cluster my standard errors by customer. Due to the conditional nature of the models, the sample for

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[10] Under 5% of PMs are promoted before the historical data begins, so, I impute role experience for these PMs (see Huckman *et al.*, 2008). Substituting a wide range of values to check robustness does not change the results.

[11] A Hausman test for each model rejects the null hypothesis (p<0.01) that the estimators from the logit (unconditional maximum likelihood) and conditional logit (conditional maximum likelihood) are both consistent. In the presence of customer effects, the conditional maximum likelihood estimator is consistent and efficient (Greene 2003).

analysis does not include projects from customers with only one project in the sample, or projects in which the dependent variable does not vary across all of the customer's projects. This yields a final sample of 454 and 409 projects for effort and schedule adherence, respectively.

My quality measure is a count variable. As I wish to control for time-invariant attributes of customers that impact quality and the data exhibit overdispersion, I use a conditional fixed effects negative binomial model (Cameron and Trivedi, 1998; Hausman, Hall, and Griliches, 1984). Since the model conditions on the total count with a customer, it eliminates all instances having only one observation per group and also those groups for which the dependent variable never varies from zero. Combined with the fact that all projects do not conduct acceptance testing, this yields a final sample of 349 projects.[12]

RESULTS AND ANALYSIS

Table 2 displays results from the models that test the relationship between effort adherence, schedule adherence, and team familiarity. Columns 1 and 2 show that overall team familiarity is positively and significantly related to effort adherence. Column 2 includes the interaction of team familiarity and project complexity; here, too, the coefficient is positive and significant, suggesting moderation.[13] In Column 3, team familiarity is divided into the two separate measures and, as Hypothesis 1 predicts, hierarchical team familiarity is positively and significantly related to effort adherence. Increasing hierarchical team familiarity by one standard deviation and calculating the average of the predicted change in all projects within the sample

[12]Another empirical approach might have employed hierarchical linear modeling (HLM) for all dependent variables. HLM can be used properly if data are nested in levels (e.g., individuals in teams or students in schools (Singer and Willett, 2002)). However, as discussed by Reagans et al. (2005), HLM is not appropriate in a setting such as mine, since project teams have "overlapping membership" and my performance variables are at the team level.

[13] Evaluating the sign and significance of the interaction coefficient in a nonlinear model is not sufficient to examine moderation (Hoetker, 2007). As discussed below, I also plot the relationship and find support for moderation. I do not show the figures for overall familiarity since this paper focuses on the hierarchical and horizontal relationships.

yields a 13.5% increase in the probability of adherence.[14] The results do not support Hypothesis 2, as the coefficient for horizontal team familiarity is positive but not significant.

***************************INSERT TABLE 2 HERE***************************

Column 4 includes the interaction of the two team familiarity variables with complexity. While the interaction of horizontal team familiarity and complexity does not significantly differ from zero at conventional levels, the interaction of hierarchical team familiarity with complexity is positive and significant. The sign and significance of the coefficient are insufficient to evaluate Hypothesis 3A, as concern remains as to whether the direction of the interaction effect changes over the support of the distribution (Ai and Norton, 2003; Hoetker, 2007).

To address this concern, I plot the *net* effect of familiarity and project complexity (i.e., both main effects and the interaction effect) on the probability of project success, for the respective measure (Haas and Hansen, 2005; Hoetker, 2007). Figure 1a shows examples of the impact of project complexity on effort adherence for high and low hierarchical team familiarity (one standard deviation above the mean and no prior experience, respectively). Increasing complexity decreases the probability that a project will adhere to its effort budget. However, as the figure shows, this negative effect is moderated by a higher hierarchical team familiarity.

***************************INSERT FIGURE 1 HERE***************************

Next I examine the relationship between the predictors and schedule adherence. In Columns 5 and 6 of Table 2, the coefficient on overall team familiarity is positive although not significant, while the coefficient on the interaction term in Column 6 is positive and significant.

[14] Since a point in the data is unlikely to have the mean values for all variables, it is useful to calculate the change in probability for all observations as a result of the change in the variable of interest and then average these changes, rather than calculate an average change (Hoetker, 2007; Train, 1986). This process is complicated in the conditional logit, as the model does not estimate values for the fixed effects (Greene, 2003). To estimate an intercept for each customer, I calculate the estimated probability using values in the data and coefficients from the model. I then calculate an intercept for each group that sets the average predicted probability for a customer's projects equal to the actual probability of adherence for that customer. The change can also be interpreted using the fitted odds ratio. An increase of one standard deviation in hierarchical team familiarity yields a fitted odds ratio of 1.73.

In Column 7, hierarchical team familiarity is positively and significantly (at the ten percent level) related to schedule adherence, providing support for Hypothesis 1. Interpreting the coefficient, an increase of one standard deviation yields an increase of 6.9% in the average predicted change in all projects.[15] I do not find support, however, for Hypothesis 2, as the coefficient on horizontal team familiarity is negative and not significant at conventional levels. Examining the interaction coefficients in Column 8, I do not find support for Hypothesis 3B, although I do for Hypothesis 3A, as the coefficient for the interaction of hierarchical team familiarity and complexity is positive and significant, at the ten percent level.

Figure 1b shows results different from those in Figure 1a, since the coefficient for complexity is now positive (although not significant). For project teams with low hierarchical team familiarity, increasing complexity decreases the probability of schedule adherence (due to the negative interaction term, i.e., teams with no prior experience working together have a negative value since the variable has been standardized). Alternatively, project teams with high hierarchical team familiarity show an increasing probability of schedule adherence with increasing complexity due primarily to the positive interaction term.

Table 3 summarizes results from the models that test the relationship between quality and team familiarity. While the coefficient for overall team familiarity is negative and significant in Columns 1 and 2 (implying that increases in team familiarity are related to fewer expected defects), the coefficient for the interaction term of familiarity and complexity in Column 2 is not significant, although it is negative. Column 3 shows the split of team familiarity. I do not find support for Hypothesis 1, although as Hypothesis 2 predicts, horizontal team familiarity is positively and significantly related to quality performance. An increase of one standard

[15] This is calculated as it was for effort adherence. A one standard deviation increase in familiarity yields a fitted odds ratio of 1.52.

deviation in horizontal team familiarity results in a 21.2% decrease in expected defects. Examining the interaction coefficients in Column 4, I fail to find support for either Hypothesis 3A or 3B. The coefficient on horizontal team familiarity and complexity is negative although not significant at conventional levels.

***************************INSERT TABLE 3 HERE***************************

Evaluating Selection

Selection bias is an important concern when examining individuals' repeated experience working together. As an organization, Wipro is divided into multiple business units, which consist of industry-focused verticals typically including 1,000 to 5,000 people each. The marketing, selling, and staffing of projects take place at the vertical level. Project teams are not formed to execute multiple projects in succession, and do not stay together in their entirety from one project to the next. Rather, when a project is completed, the team is dispersed to work on new opportunities. It is not the case, though, that all pairs of individuals across Wipro have the same expected probability of working together. Since staffing takes place at the vertical level, it is more likely that individuals within the same vertical will work together repeatedly, as compared to individuals across verticals (although there is employee movement across verticals, too).

During the sample period, Wipro was typically supply-constrained—i.e., the utilization rate of personnel was close to the maximum practical value. As such, individuals usually did not wait long between completing a project and being assigned to the next one. Two individuals completing the same project, therefore, were more likely to work together again, compared to any two randomly chosen individuals, since the two on the same project would both have become available for reassignment at the same time. These two points do not, in and of themselves, cause concern; rather, they help to make sure that I observe individuals working together repeatedly, while also generating variance in team familiarity.

At least two potential issues remain that could bias my results: (1) Is team familiarity a criterion for staffing project teams? (2) Can project managers select specific team members? The concern with the first point is that a senior manager or human resources staff member might learn who functions well (or poorly) together and construct teams accordingly. If this were the case, then any performance benefits of team familiarity might not be from prior experience together, but rather from personality fit. The second point includes both the fit concern and the worry that, if project managers select their own team members, they might use prior experience to learn who is most skilled and always choose to work with these individuals going forward, while avoiding less skilled team members.

To evaluate these concerns, it is necessary to examine how projects are staffed. The first step in project staffing is the estimation of the effort and schedule for a new project, which is completed by sales personnel at Wipro. The global software services market is competitive with major Indian (e.g., TCS, Infosys, Wipro, Satyam, and HCL) and non-Indian (e.g., IBM and Accenture) companies. As a result, sales people cannot add undue slack to estimates, or they risk losing a project. The project manager (or managers in the case of large projects) is not assigned to a project until after the customer agrees to the estimates, which provide guidelines for staffing the project (e.g., Java programmer with two years' experience). The project manager does not request specific personnel or even the pool of personnel, but rather the sub-unit staffing group provides individuals who meet the estimates' requirements. During my interviews of project managers, senior managers, and human resources personnel at the company, the notion that team familiarity is used as a criterion for staffing was uniformly rejected.

I empirically examine whether team familiarity might be used as a staffing criterion by looking to see if any of the team familiarity measures are significantly related to a projects' original effort or schedule estimates. A significant relationship might imply that either: (a) sales personnel anticipated the eventual team familiarity and tightened their estimates accordingly; or (b) staffing personnel recognized that an estimate was more challenging and so responded by assigning a team familiar with one another. Table 4 presents regression results using the logarithm of the original effort and schedule estimates as dependent variables. I run separate models using overall team familiarity as well as hierarchical and horizontal team familiarity. While the models are highly predictive, none of the team familiarity measures are significantly related to the estimates, at conventional levels.

****************************INSERT TABLE 4 HERE****************************

The second question is whether project managers can select individual engineers. As noted, team members are staffed to a project based on estimates made by sales personnel. However, the project manager does have a formal right to reject any individual sent by the staffing unit. Interviews across the company suggest that organizational norms strongly and effectively discourage the use of this power.[16] Given the supply constraints that Wipro faces in recruiting and training engineers, project managers are evaluated on their ability to help struggling team members. Nevertheless, the rejection power could prove problematic if used systematically to remove certain members. To test for this possibility, I use a Cox proportional hazards model (Cleves, Gould, and Guiterrez, 2004).[17]

I examine two sets of team member interactions: (1) every dyad of individuals working together and (2) each project manager—team member dyad in the sample. The latter analysis

[16] Ideally I would examine cases in which project managers rejected individuals. However, managers noted that gsince the phenomenon is uncommon, Wipro does not track this data.
[17] I also analyze the same models using logistic regression and find the similar pattern of results described below.

allows me to more directly examine any selection running directly through the project manager role. Failure is defined as the pair not working together again on the subsequent project. I run the model to see if poor performance on any of the performance variables predicts failure. As shown in Table 5, I find no variables to be significant predictors of failure. While these results, together with Table 4, cannot conclusively reject the possibility of selection, they do increase my confidence that selection bias is not the primary reason behind the results reported in this paper.

***************************INSERT TABLE 5 HERE***************************

Discussion

Overall team familiarity for an entire project team (i.e., project manager(s), middle manager(s), and project engineer(s)) is positively and significantly related to effort adherence and quality performance, but not to schedule adherence. The interaction of overall team familiarity and project complexity is positively and significantly related to the two adherence measures, but not to quality of the project's output. Thus, in at least some situations, team familiarity is more valuable for reaching performance standards when problem solving activities are more difficult.

Separating the types of team familiarity to individually examine *hierarchical* team familiarity as well as *horizontal* team familiarity provides greater insight than simply considering the undifferentiated phenomenon. In support of Hypothesis 1, this study's results show that hierarchical team familiarity is positively related to both effort and schedule adherence, at the ten percent significance level for the latter measure. Also, in partial support of Hypothesis 3A, the relationship between complexity and each adherence measure is shown to be moderated by hierarchical team familiarity (at a ten percent significance level for schedule adherence).

These results suggest the adherence measures may possess characteristics that respond well to hierarchical team familiarity. I posit that a key detail may be the measures' observability in process. The company has tools in place that make it relatively easy for a manager to track how a project is performing with respect to both its effort budget and schedule. These tools are not substitutes for team familiarity, but rather enhance the value of team familiarity as the tools provide information at a project level, but managers make decisions with respect to the actions of individuals (e.g. allocating an individual to complete a certain part of the code in a project). Familiarity between the project manager and team members can have numerous potential performance benefits, but these may be most useful when performance is observable in process, since then project managers can do what their titles suggest: manage the project. For example, if engineers feel psychologically safe to share what is taking place, but the manager cannot act upon the information quickly enough or at all, then this value of team familiarity may be lost.

Considering quality performance, this study's findings show that just as Hypothesis 2 predicts, horizontal team familiarity is positively and significantly related to project quality performance. Given the challenges in observing software quality during development, the project engineers' close proximity to the software code may mean that horizontal familiarity helps them to effectively coordinate low-level problem-solving activity. More generally, these results indicate that horizontal and hierarchical team familiarity may differentially relate to various performance measures. This distinction may parallel the literature on organizational structure, which suggests that organizations seeking efficient performance should organize in a hierarchical or bureaucratic structure, while those seeking creative and innovative performance should seek a flatter, organic structure (Burns and Stalker, 1961; Lawrence and Lorsch, 1967). In my setting, teams with higher hierarchical team familiarity perform better on effort and schedule adherence – measures of project efficiency (Faraj and Sproull, 2000), while teams with higher horizontal team familiarity perform better on quality. These findings suggest that the type of familiarity needed by an organization may depend on the organization's strategy.

My results also offer insight into how firms develop a sustainable competitive advantage. If an organization is to maintain a competitive advantage then its resources and capabilities must be difficult to copy (Barney, 1991). As noted by Hatch and Dyer (2004), "human capital is most valuable and *most inimitable* when it is firm-specific (p. 1155, italics added)." (see also, Hitt *et al.*, 2001; Lepak and Snell, 1999; Reed and Defillippi, 1990) Recent work on firm-specific experience supports the inimitability argument as Huckman and Pisano (2006) find that the quality of a surgeon's performance improves with cumulative experience, but only when surgeries are conducted at the same hospital. They suggest that the mechanism is familiarity with organizational specific assets, such as team members (see also, Edmondson, Bohmer, and Pisano, 2001; Groysberg, Lee, and Nanda, 2008). Viewed in the light of this prior work, my findings show how one type of firm-specific experience, team familiarity, may contribute to building a sustainable competitive advantage.

Limitations

This work has several limitations. First, a possibility exists that any non-random assignment of individuals to teams could have biased results. While my interviews and investigatory models find no evidence of selection, I cannot categorically rule out the possibility. Second, the lack of a significant coefficient for some measures of familiarity is not a rejection of the respective hypotheses, but a lack of support. A larger sample or different experimental design may provide additional insight with respect to these relationships. Finally, this study is from one firm in one industry, so its findings may not generalize to other settings. This limitation is a necessary, but undesirable consequence of the rich quantitative data and fieldwork that permitted me to draw together deep knowledge of the firm with large-scale empirical testing of the research questions.

CONCLUSION

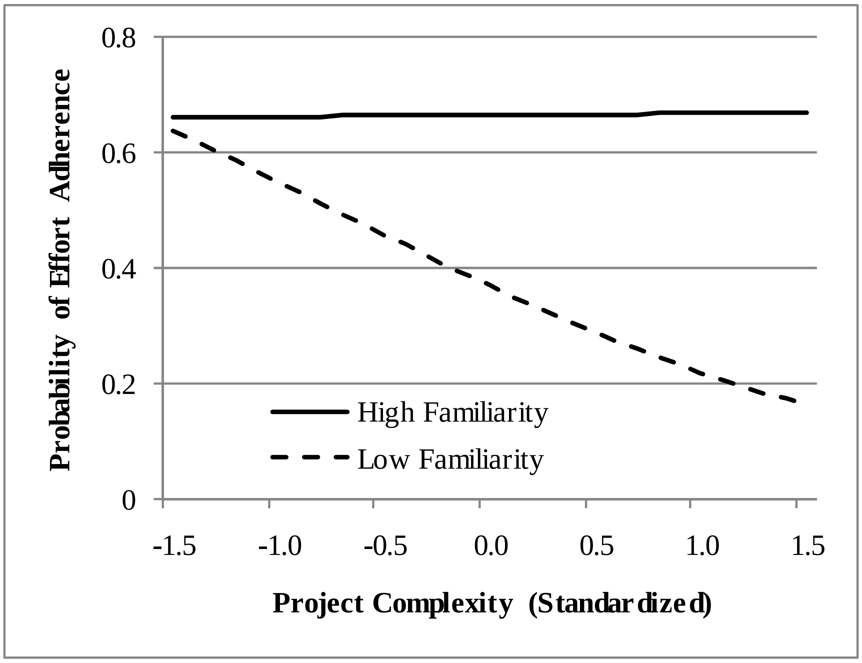
It has been asserted that successfully managing knowledge work and workers will be the primary competitive differentiator in the 21st century (Drucker, 1999; Haas and Hansen, 2007; Teece *et al.*, 1997). In this paper, I examine a fast-moving, knowledge-based industry to explore the microfoundations of capabilities as I show that capabilities are not simply aggregations of individual skills and experience, but rather that they depend, in part, on connections between individuals developed through work experience: team familiarity. This study's empirical analysis highlights the importance of examining not just *whether* team members have worked together, but *which* team members have worked together.

My findings also offer important opportunities for managerial action. Ethiraj et al. (2005) posit that "our results demonstrate that project profitability differences could be a function of differences in the way the same resources are deployed by the firm (p. 43)" (cf. Penrose, 1959). My findings support this proposition. If knowledge and experience lead to the development of capabilities, then organizations need to take knowledge creation, application, and transfer ever more seriously (Nonaka, 1994; Senge, 1990). Since learning is path-dependent and previous experience may determine subsequent action, then explicitly tracking, understanding, and managing the accumulation of experience are all important (Edmondson, 2002; Garud, 1997; Levitt and March, 1988). Incorporating information about experience into internal operations is difficult (Garud and Kumaraswamy, 2005) and will require significant action and investment (e.g., tracking experience, creating assignment algorithms that balance a firm's and individuals' needs, etc.), but in so doing may generate new opportunities to create a competitive advantage.

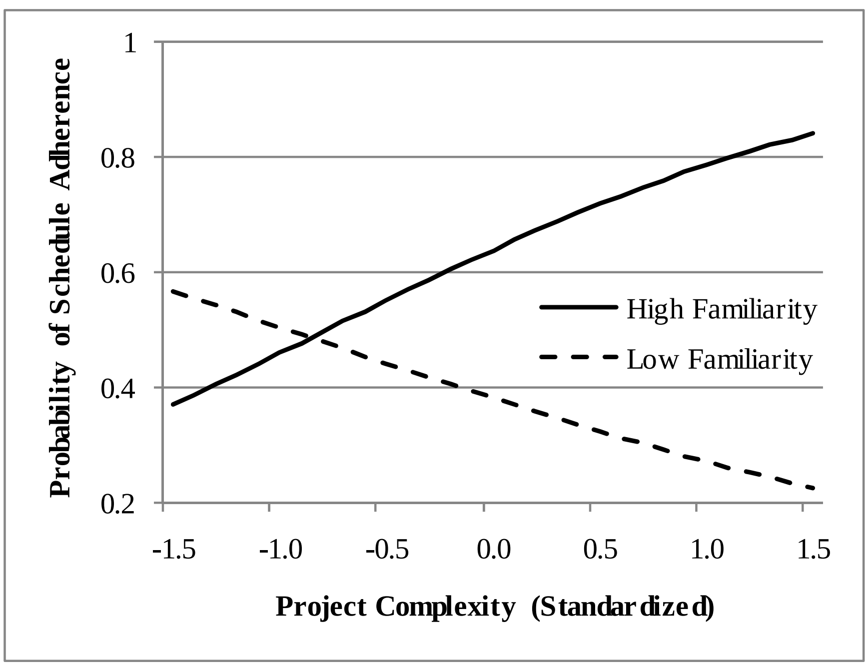
This study also highlights the need for further work moving up and down levels of analysis (cf. Hackman, 2003) to explore the mechanisms that develop and maintain capabilities. While Ethiraj et al. (2005) identify a valuable capability within one firm at the project level, I move down a level to examine how individual interactions across and between hierarchical levels affect this capability. Further work should seek to understand how individual and team-level interactions contribute to capability development and competitive outcomes. Also, there is a need to understand what processes are driving the relationships found in this study (e.g., as in Reagans *et al.*, 2008). For example, does familiarity with front-line workers help managers allocate work more effectively or respond to changing circumstances in a more agile manner than they would be able to do otherwise?

As a final point, while low-level exploration of capabilities within one firm brings important insights there is also a need to move back up from the micro-level to understand diversity across firms. This is necessary to appreciate how these differences affect firms' responses to competition and the resulting competitive outcomes (e.g. Henderson and Clark, 1990; Tripsas and Gavetti, 2000). Altogether, the ongoing exploration of capabilities at ever finer levels will help to increase our understanding of the source of organizational capabilities, how they evolve, and how they contribute to the competitive success of organizations.

FIGURES & TABLES



a. Net effect of hierarchical team familiarity and project complexity on effort adherence.



b. Net effect of hierarchical team familiarity and project complexity on schedule adherence.

Figure 1. Plots of the effects of hierarchical team familiarity and project complexity on the probability of success for the effort and schedule adherence, respectively.

Table 1. Summary statistics and correlation table of dependent, independent, and control variables of interest (*n*= 454, except for schedule adherence and post-delivery defects, where *n* = 409 and 349, respectively).

Variable	Mean	σ	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12
1. Effort Adherence	0.75	0.43	0.00	1.00												
2. Schedule Adherence	0.83	0.38	0.00	1.00	**0.38**											
3. Post-Delivery Defects	27	112	0	1396	-0.09	-0.10										
4. Overall Team Familiarity	0.41	0.51	0.00	3.83	0.09	0.07	-0.08									
5. Hierarchical Team Familiarity[a]	0.45	0.57	0.00	3.79	0.07	0.10	-0.09	**0.85**								
6. Horizontal Team Familiarity[a]	0.27	0.36	0.00	2.60	**0.12**	0.08	-0.07	**0.81**	**0.71**							
7. Project Complexity[a]	3.38	1.23	-1.24	7.66	-0.04	-0.05	**0.34**	**-0.17**	**-0.12**	**-0.09**						
8. Team Role Experience[a]	1.26	0.59	0.13	4.63	0.06	0.10	-0.08	**0.25**	**0.23**	**0.21**	-0.07					
9. Fixed Price Contract	0.69	0.46	0.00	1.00	0.08	**-0.03**	-0.12	**0.09**	0.09	0.05	-0.05	**0.14**				
10. Offshore[a]	0.85	0.16	0.23	1.00	**-0.10**	-0.08	-0.03	0.09	0.11	0.08	**-0.12**	**-0.11**	**-0.12**			
11. Log (Estimated Effort)[a]	8.67	1.10	6.11	12.55	0.05	-0.04	**0.36**	**-0.20**	**-0.17**	-0.08	**0.70**	0.00	**-0.15**	**-0.15**		
12. Log (Team Size)[a]	2.57	0.76	1.39	5.02	-0.02	-0.04	**0.31**	**-0.19**	**-0.15**	-0.06	**0.62**	0.04	**-0.09**	**-0.15**	**0.85**	
13. Log (Estimated Duration)[a]	5.28	0.64	3.26	7.01	-0.01	0.00	**0.17**	**-0.12**	**-0.10**	-0.07	**0.49**	0.01	**-0.17**	-0.06	**0.74**	**0.57**

Table 2. Summary results of the conditional logistic regression of effort adherence and schedule adherence on team familiarity (*n* = 454 and 409, respectively).

	Dependent Variable: Effort Adherence				Dependent Variable: Schedule Adherence			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Overall Team Familiarity	0.374**	0.518**			0.075	0.300		
	(0.150)	(0.221)			(0.179)	(0.219)		
Overall Team Familiarity × Project Complexity		0.280**				0.635**		
		(0.133)				(0.256)		
Hierarchical Team Familiarity[a]			0.549***	0.684***			0.416*	0.575*
			(0.210)	(0.236)			(0.253)	(0.310)
Horizontal Team Familiarity[a]			0.136	0.007			-0.108	-0.024
			(0.229)	(0.234)			(0.254)	(0.304)
Hierarchical Team Familiarity × Project Complexity				0.415**				0.673*
				(0.195)				(0.383)
Horizontal Team Familiarity × Project Complexity				-0.120				0.131
				(0.221)				(0.334)
Project Complexity[a]	-0.468**	-0.403**	-0.469**	-0.405**	-0.126	-0.015	0.058	0.061
	(0.198)	(0.198)	(0.192)	(0.196)	(0.211)	(0.236)	(0.185)	(0.211)
Offshore[a]	-0.041	-0.038	-0.069	-0.055	-0.552**	-0.526**	-0.579**	-0.552**
	(0.228)	(0.235)	(0.245)	(0.257)	(0.232)	(0.236)	(0.232)	(0.234)
Log (Estimated Project Effort)[a]	1.310***	1.293***	1.280***	1.318***	-0.151	-0.124	-0.391	-0.234
	(0.444)	(0.448)	(0.443)	(0.445)	(0.366)	(0.380)	(0.390)	(0.365)
Log (Max Team Size)[a]	-0.726**	-0.696**	-0.772**	-0.808**	-0.201	-0.151	-0.140	-0.083
	(0.316)	(0.323)	(0.313)	(0.315)	(0.292)	(0.302)	(0.307)	(0.300)
Observations	454	454	454	454	409	409	409	409
McFadden's Pseudo R^2	0.1377	0.1467	0.1572	0.1687	0.1769	0.2050	0.1883	0.2242
Log Pseudolikelihood	-137.0	-135.6	-133.9	-132.1	-93.73	-90.53	-92.43	-88.34
Wald chi-squared	123.0***	87.47***	112.1***	106.7***	85.79***	113.8***	114.1***	124.6***

Notes: *, ** and *** denote significance at the 10%, 5%, and 1% levels, respectively. All models condition on the customer (i.e., include customer fixed effects). Standard errors are clustered by customer and are heteroskedasticity robust. Models include, but results are not shown, for role experience, project duration, and the indicator variables for number of software languages, type of software language, number of technologies, start year, architect, and fixed price contract.
[a] Variable is standardized by subtracting the mean and dividing by the standard deviation.

Table 3. Summary results for the regression of post-delivery defects on team familiarity (n = 349).

	Dependent Variable: Post-Delivery Defects			
	(1)	(2)	(3)	(4)
Overall Team Familiarity	-0.238**	-0.276**		
	(0.111)	(0.115)		
Overall Team Familiarity × Project Complexity		-0.121		
		(0.102)		
Hierarchical Team Familiarity[a]			-0.008	0.022
			(0.131)	(0.138)
Horizontal Team Familiarity[a]			-0.238**	-0.275**
			(0.121)	(0.125)
Hierarchical Team Familiarity × Project Complexity				0.072
				(0.149)
Horizontal Team Familiarity × Project Complexity				-0.194
				(0.145)
Project Complexity[a]	0.646***	0.627***	0.652***	0.658***
	(0.134)	(0.134)	(0.135)	(0.136)
Offshore[a]	-0.055	-0.056	-0.058	-0.054
	(0.078)	(0.078)	(0.079)	(0.079)
Log (Estimated Project Effort)[a]	0.097	0.083	0.111	0.090
	(0.218)	(0.217)	(0.216)	(0.217)
Log (Max Team Size)[a]	-0.172	-0.181	-0.161	-0.178
	(0.175)	(0.175)	(0.174)	(0.174)
Constant	-1.577***	-1.575***	-1.598***	-1.581***
	(0.347)	(0.351)	(0.348)	(0.352)
Observations	349	349	349	349
Log (Pseudo)likelihood	-711.9	-711.3	-710.9	-709.9
Wald chi-squared	86.22***	95.81***	90.91***	102.0***

Notes: *, ** and *** denote significance at the 10%, 5%, and 1% levels, respectively. All models condition on the customer (i.e. include customer fixed effects). Models include, but results are not shown, for role experience, project duration, and the indicator variables for number of software languages, type of software language, number of technologies, start year, architect, and fixed price contract.

[a] Variable is standardized by subtracting the mean and dividing by the standard deviation.

Table 4. Summary results for regression of effort estimate and schedule estimate (duration) on team familiarity (n = 454).

	Dep Var: Log Duration Estimate		Dep Var: Log Effort Estimate	
	(1)	(2)	(3)	(4)
Overall Team Familiarity	-0.003		0.012	
	(0.018)		(0.019)	
Hierarchical Team Familiarity[a]		-0.048		0.001
		(0.029)		(0.037)
Horizontal Team Familiarity[a]		0.009		0.020
		(0.020)		(0.026)
Project Complexity[a]	-0.011	-0.010	0.195***	0.196***
	(0.033)	(0.032)	(0.030)	(0.030)
Log (Estimated Project Effort)[a]	0.561***	0.558***		
	(0.050)	(0.050)		
Log (Estimated Duration)[a]			0.673***	0.674***
			(0.062)	(0.062)
Log (Max Team Size)[a]	-0.066	-0.068	0.487***	0.486***
	(0.046)	(0.046)	(0.051)	(0.051)
Observations	454	454	454	454
Overall R^2	0.583	0.581	0.818	0.819
F-Statistic	46.94***	50.62***	213.5***	205.3***

Notes: *, ** and *** denote significance at the 10%, 5%, and 1% levels, respectively. All models include customer fixed effects. Standard errors are clustered by customer and are heteroskedasticity robust. Models include, but results are not shown, for role experience, offshore, and the indicator variables for number of software languages, type of software language, number of technologies, start year, architect, and contract type.

[a] Variable is standardized by subtracting the mean and dividing by the standard deviation.

Table 5. Summary results of Cox hazard models to examine potential selection effects on project performance.

	All Dyads	Project Manager - Team Member Dyads
	(1)	(2)
Effort Adherence	-0.0065	-0.0259
	(0.0263)	(0.0223)
Schedule Adherence	-0.0083	-0.0044
	(0.0198)	(0.0189)
Post-Delivery Defects	0.00002	0.00003
	(0.00004)	(0.00005)
Fixed Price Contract	0.0183	0.0183
	(0.0244)	(0.0242)
Offshore	-0.0182	-0.0477
	(0.0800)	(0.0753)
Complexity	0.0046	-0.0103
	(0.0083)	(0.0098)
Log (Estimated Project Effort)	-0.0364	0.0112
	(0.0168)	(0.0171)
Log (Max Team Size)	0.0471	-0.0086
	(0.0211)	(0.0179)
Log (Estimated Duration)	0.0586	0.0541
	(0.0192)	(0.0238)
Observations	126,731	14,361
Log Likelihood	-1,357,119	-127,210

Notes. *, ** and *** denote significance at the 10%, 5%, and 1% levels, respectively. The following variables are included in the regressions but are not shown in the table: project start year, software language, # of languages, # of technologies, and customer fixed effects. Standard errors are clustered by project.

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