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Efficacy of R&D work in offshore captive centers: An empirical study of task characteristics, coordination mechanisms, and performance

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Abstract:

Seizing the latest technological advances in distributed work, an increasing number of firms have set up offshore captive centers in emerging economies to carry out sophisticated R&D work. We analyze survey data from 132 R&D captive centers established by foreign multinational companies in India to understand how firms manage the execution of distributed innovative work. Specifically, we examine the performance outcomes of projects employing different technology-enabled coordination strategies to manage their interdependencies across multiple locations. We find that modularization of work across locations is largely ineffective when the underlying tasks are less routinized, less analyzable, and less familiar to the captive center. Coordinating based on information sharing across locations is effective when the captive center performs tasks that are less familiar to it. A key contribution of our work is the explication of the task contingencies under which coordination based on modularization versus information sharing yield differential performance outcomes.

Keywords: Offshoring, Captive Centers, R&D, Coordination, Distributed Work, Modularization, Information Sharing, Performance, knowledge-intensive work

Efficacy of R&D Work in Offshore Captive Centers: An Empirical Study of Task Characteristics, Coordination Mechanisms and Performance

Introduction

The offshoring of R&D and new product development (NPD) by multinational corporations (MNCs) to emerging economies such as India and China is a relatively new phenomenon, although it is growing significantly. Such distributed and offshored R&D could be performed either by the MNC's wholly owned *captive centers* or by third-party vendors and governed by a contractual agreement. The former is typically referred to as *captive offshoring* whereas the latter as *offshore outsourcing*. It is well known that the performance of distributed work is adversely impacted by failures of *cooperation* – i.e., misaligned incentives, as well as failures of *coordination*, i.e., misaligned actions. It is intuitive that coordination fails when cooperation fails; therefore, aligning incentives is the first step towards achieving coordination. However, a large body of literature has established that coordination failures frequently occur even when incentives are fully aligned; i.e., when there is no cooperation failure (Simon, 1947; Schelling, 1960; Grant, 1996; Heath and Staudenmayer, 2000; Holmstrom and Roberts, 1998). Our study advances this rich body of work by studying how organizations coordinate distributed knowledge intensive work in the presence of aligned incentives. Captive offshoring of R&D is an attractive setting to study this question because (a) it involves the difficult task of coordinating knowledge intensive work between geographically distributed teams, and (b) these teams belong to the same organization and are subject to the same incentives, control systems and authority structures including 'recourse to fiat', that leads to higher levels of aligned incentives than is available between teams from different firms working together (Williamson, 1985; 1991) such as in offshore outsourcing.

Achieving coordinated action depends on the presence of sufficient common ground – knowledge that is shared and known to be shared – though exactly how much common ground is needed is something that varies with the situation and the nature of coordination mechanism utilized (Schelling, 1960; Puranam et al, 2012). Prior literature has suggested two generic categories of coordination mechanisms for building and maintaining common ground, namely, *information sharing* and *modularization* (March and Simon, 1958; Galbraith, 1977; Puranam et al, 2012). The *information sharing* strategy involves interdependent agents communicating with each other on an ongoing basis to dynamically update common ground. A *modularization* strategy, involves limited ongoing interaction between the agents. Here an 'organization designer' maps out the nature of interdependence, redesigns tasks such that interactions between the interdependent agents happen via a 'well-specified' interface, and places this interface in common ground. Interfaces, conceptualized as a description of how elements of a system interact with each other economize on the need for ongoing communication and the amount of knowledge held in common ground (Baldwin and Clark 2000, Simon 1962, Ulrich and Eppinger 1999).

These two strategies are well researched in the literature as feedback vs. plan (March and Simon, 1958; Thompson, 1967; Tushman and Nadler, 1978), tight vs. loose coupling (Orton and Weick, 1990), or integration vs. modularization (Baldwin and Clark, 2000; Sanchez and Mahoney, 1996), However, prior research on coordinating offshored work has primarily focused on simpler tasks such as IT services or back office operations (Dibbern et al, 2008; Oshri et al, 2007; Srikanth and Puranam, 2011). Whereas these studies find that both modularization and information sharing are useful for coordinating offshored work, they do not reach any conclusions regarding the superiority of one of these mechanisms for any given task type. Therefore, it is currently unclear how the nature of work, the extent of interdependence and the coordination mechanisms employed interact to generate high performance – *i.e., what combinations of task characteristics and coordination mechanisms yield high performance in the context of interdependent knowledge work*?

We study this question in the context of captive offshoring which has grown rapidly in the last decade (Khurana 2006; Lewin, Massini and Peeters, 2009). Whereas early efforts at offshoring R&D primarily involved simple tasks, especially aimed at customizing the MNC's technology to local requirements (Rugman, 1981; Kuemmerle, 1999), more recently, several scholars have argued that R&D activity undertaken by offshore captive centers are highly sophisticated and strategically important (Mudambi and Venzin, 2010; Kumar and Puranam, 2012). Therefore, understanding high-performance work configurations in this context is of significant practical significance. Further, from a theoretical viewpoint, it is now well recognized that coordinating interdependent work, especially complex knowledge-intensive work, distributed across geographic locations can be extremely challenging (Hinds and Kiesler, 2002). Prior research finds that rich ongoing face-to-face communication is especially desirable when coordinating complex tasks (Kraut et al; 2002; Olson et al, 2002). For example, Srikanth and Puranam (2014) found that in their sample all co-located projects depended mainly on ongoing communication for coordinating, and none made significant efforts towards modularization. Much prior work assumes that 'feedback' (March and Simon, 1958) or 'mutual adjustment' (Thompson, 1967) is essentially ongoing communication. Not only is this powerful, in co-located R&D teams it is also essentially free, and is perhaps even taken for granted in prior research. However, this important coordination mechanism is not available when R&D teams are geographically distributed. Prior work on media richness finds that even 'rich media' such as videoconferencing are not particularly useful in generating adequate common ground necessary for achieving coordination (Kraut et al, 2002; Olson et al, 2002). Specifically, effective information sharing is no longer effortless or free and careful investments need to be made in technologies and in developing routines and processes to make information sharing practically useful in distributed work (Kraut et al, 2002; Srikanth and Puranam, 2010; 2011; Mani et al. 2012). Therefore, the consideration of different strategies to achieve coordination such as between modularization vs. information sharing and their costs vs. benefits becomes more salient and theoretically more important in distributed work compared to co-located work. Prior theories that rely on a model of co-located organization may not be entirely applicable to the context of offshored R&D.

Whereas these concerns regarding coordinating are applicable for work that is distributed between say, New York-San Francisco or New York-Bangalore, we believe the question assumes greater importance in the latter situation, because in addition to geographic distance, project teams need to coordinate across greater 'psychic' distance arising from differences in language, culture, time zones, status and norms (Johanson and Vahlne, 1977; 2009; Levina and Vaast, 2008). With increasing 'psychic' distance, communication alone may not improve shared understanding (Clark, 1996), and the information sharing strategy needs to be that much more sophisticated and perhaps carry a much greater volume of information to generate common ground making this strategy more expensive and perhaps less effective. Therefore, the choice between modularization versus information sharing becomes an important strategic choice. Investigating the performance implications of task characteristics and coordination mechanisms in the context of offshored R&D can be considered a more extreme sample of the general phenomenon of distributed work, but one where the consequences for these choices are likely to be in particularly high relief and therefore, subtle effects more easily identified.

Although both captive offshoring and offshore outsourcing of R&D have the same coordination problems discussed above, we believe the focus on captive offshoring helps improve our understanding of choice of coordination mechanisms since cooperation concerns are minimized in this setting. Mani et al. (2010) point to the difficulty in separation of cooperation and coordination concerns in their study of effectiveness of different governance structures in business process outsourcing. It is typically unclear whether the choice between modularization versus information sharing is primarily a response to coordination concerns or whether cooperation concerns also influence this choice. For example, Aron and Singh (2005) suggest that firms largely elect to vertically integrate, through captive centers, tasks involving high levels of structural and operational risk that do not lend themselves to contracting. However, as the knowledge based view of the firm points out (Kogut and Zander, 1992), internalization may be a strategic response to increasing interdependence as well as to increasing incompleteness of contracts. Given our focus on coordination, studying captive offshoring is more appropriate than studying offshore outsourcing, since captives are hierarchical organizations that are more likely to be free of cooperation concerns such as the potential for opportunistic behavior (Williamson, 1991).

A key assumption underlying our study is that advanced ICTs play a critical role in coordinating knowledge-intensive work between the captive center and the headquarters of the MNC. Dramatic improvements in ICTs provide new opportunities for organizing and coordinating interdependent work across geographically dispersed units (Majchrzak et al, 2005; Bailey et al. 2010). Other work has already documented the importance of IT for coordinating distributed work – be it in the form of communication technology, such as email, video conferencing, etc., information sharing technology such as file sharing systems, concurrent versioning systems, etc., technology enabled standards such as EDI, XML, etc., and shared systems for design and validation such as CAD/CAM, among others, that enable a more modular approach to coordination (Olson et al, 2002; Kraut et al, 2002; Bailey et al, 2010; Mani et al. 2010; Bailey and Leonardi, 2008; Argyres, 1999; Thomke, 2006). Our study enables managers to choose the right technology investments given the nature of tasks performed by identifying high performing configurations of task characteristics and coordination mechanisms. This is crucial since both modularization and information sharing require specific investments in order to be effective, and managers cannot switch easily from one coordination approach to another.

Our analyses use data collected from 132 captive R&D centers located in India that perform R&D and NPD work for global MNCs. We first consider the impact of various attributes of the offshored task such as the *degree of routineness*, the *extent of analyzability,* and the *degree of familiarity* of these tasks, on various performance outcomes. Next, we examine if the *level of interdependence* between the captive center and other locations of the MNC in executing the task moderates the impact of the task attributes on performance outcomes. Finally, we analyze three way interactions to examine how the relationships among task attributes and interdependence are impacted by the choice of coordination mechanism –*modularization* versus *information sharing* - used.

Results from our study emphasize the nature of organizations as systems of coordinated activity and show how the alignment between task attributes and choice of coordination mechanisms impacts performance. We find that modularization is more suited for work that is more routine (less variable) and analyzable (more specifiable) whereas information sharing is more suited for work that is less familiar (i.e. the captive center does not have prior task expertise). The primary contribution of our work is to demonstrate high performance work configurations in offshoring of R&D and product development work, given that the tasks analyzed are highly interdependent. Our results have important theoretical implications for scholars studying organization and coordination of distributed work as well as for practitioners who are interested in improving the performance of their distributed R&D strategies.

II. Theory and Hypotheses

In the following sections, we draw on theories of knowledge exchange and coordination in organizations to develop the key hypotheses of the study (Grant 1996; Kogut and Zander 1992; Nickerson and Zenger 2004; Puranam et al, 2012). In order to understand high performing configurations for offshoring R&D, we first describe the attributes of the offshored task and the nature of interdependence between the captive center and other locations that drive heterogeneity in coordination needs. Subsequently, we describe the two ICT-enabled coordination mechanisms – *modularization* and *information sharing* - and develop hypotheses about how their relative efficacy depends on the attributes of the offshored task.

II.A. Task Attributes

Central to coordination theory is the notion that the underlying tasks vary with respect to certain characteristics. In turn, coordination mechanisms vary in the extent to which they can effectively support the information processing and knowledge exchange needed for these different task characteristics (Thompson, 1967; Malone and Crowston, 1994). Two fundamental task characteristics that explain heterogeneity in information processing and knowledge exchange requirements, originally described by Perrow (1967) and subsequently developed in other studies (Galbraith 1977; Tushman and Nadler 1978), are *routineness* and *analyzability*.

Task routineness has been described as the extent to which problems in task execution display stability and lack variety (Perrow 1967). Teams engaged in more routine tasks encounter few unexpected situations. They face a relatively stable information environment with few exceptions (Daft and Macintosh 1981). In contrast, teams that handle tasks with low levels of routineness, frequently encounter a greater variety of problems.

Analyzable tasks are those where the team can follow objective and codifiable procedures to solve problems. There are more information cues available for the execution of analyzable tasks (Rice, 1992). In contrast, teams faced with tasks that have low analyzability have greater difficulty in identifying the kinds of information needed to solve the problem. The knowledge needed to solve tasks with low analyzability cannot be easily specified through written rules and procedures. In this case, participants are called upon to solve “non-programmed” problems (Simon 1965) that often require judgment, intuition, creativity and socialization (Kim, 1988).

While routineness and analyzability represent the inherent stability and equivocality of the underlying tasks, they do not provide any guidance on the degree to which the tasks impose new challenges for the captive center. This is because neither of these attributes speaks to the existing knowledge of the captive center and the extent to which the center would feel challenged to acquire new skills and expertise to handle the tasks in the R&D project. In order to capture this important attribute, we examine *task familiarity* as the third task attribute that impacts the informational requirements of the captive center. Task familiarity refers to the extent to which the captive center already possesses the knowledge and skills needed to carry out the tasks in the project. When task familiarity is low, the extent of new learning needed to accomplish the tasks can pose a significant challenge, especially if the captive center is expected to learn fundamentally new concepts. Since familiar tasks are more likely to exploit the existing knowledge of the captive center, task familiarity is likely to be positively correlated with project performance (Goodman and Leyden 1991; Espinosa et al. 2007; Banker and Slaughter 2000; Reagens et al. 2005). Table 1 provides an example that illustrates the distinction between these three task attributes.

INSERT TABLE 1 HERE

II.B Interdependence

In analyzing the work carried out by captive R&D centers, the informational challenges posed by the underlying task attributes have to be considered in the context of *interdependence*. This is because rarely does a captive R&D center control all the stages of work from start to finish in the input-process-output cycle of a complex process; typically they perform one or more intermediate stages in the work chain. It is a common practice for many MNCs to vertically and horizontally segment the R&D activities that are performed in the offshore captive centers (Kumar and Puranam, 2012). For example, a captive center of a pharmaceutical firm such as Merck might be dedicated to performing the clinical trial process wherein new drugs are tested for efficacy and side effects. Although this is a distinct step in the drug development value chain, the captive center nevertheless has to coordinate its work closely with other R&D centers involved in drug development in order to understand the protocols used and share the most useful data for drug design. When activities that have high interdependence with other core activities in the firm's value chain are offshored, their performance depends critically on how well the activity is coordinated (Srikanth and Puranam, 2011; Puranam and Srikanth, 2007).

Studies in coordination theory suggest that there are two generic and dichotomous approaches to coordinating work (March and Simon, 1958; Tushman and Nadler, 1977). The first, *modularization*, takes a design approach to reorganizing work activities such that interdependencies across locations is minimal and therefore reduces the need for ongoing coordination. The second, *information sharing*, coordinates by facilitating ongoing information sharing across the locations. We examine these two coordination mechanisms in the context of the work carried out by captive centers. We develop specific hypotheses about how the efficacy of these coordination mechanisms might vary based on the underlying task attributes with a goal of examining high performance work configurations in captive R&D centers.

II. C Investments in Modularization

Modularization or the degree to which work can be disaggregated and recombined is fundamental to offshoring and has been a major contributing factor in driving growth in offshoring. It refers to the degree to which a system (or a set of activities) can be decomposed into loosely coupled subsystems (or subsets of activities) that are coordinated by means of well-specified interfaces (Baldwin and Clark 2000). Successful coordination via modularization therefore depends on the ability of a designer to map out and perhaps redefine the nature of the interdependence among activities carried out by different groups or teams, and define interfaces that capture all the interactions between the different teams. Modularization (in both products and processes) can therefore, be viewed as a design strategy that emphasizes standardized interfaces whereby sub-components can be combined without loss of functionality (Sanchez and Mahoney 1996; Von Hippel 1990).

The availability of advanced ICTs has fueled the drive toward offshoring, especially of services. These technologies facilitate the digitization of work artifacts and render work portable in ways that were not possible in the past (Alavi and Tiwana 2002; Thomke 2006; Majchrzak 2005; Bailey and Leonardi

2008). Digital artifacts allow the codification of interface specifications and thereby, allow complex work to be coordinated without the need for continual interactions amongst the workers assigned to these tasks. Open source systems such as Linux and Android are examples of work that rely on modularization in order to combine distributed effort (Moon and Sproull, 2002).[2]

Modularization requires significant upfront effort in mapping diverse activities in task execution and understanding the underlying patterns of interdependence, designing interfaces and communication protocols between organizational actors, and getting buy-in for these protocols (Srikanth and Puranam, 2011). Such efforts are difficult and are typically accompanied by changes in organizational structure and business processes within the organization. For instance, Argyres (1999) documents how the use of IT tools such as a common access database of part-designs and systems for performing advanced structural analysis enabled coordination across the four firms that jointly developed the B-2 Stealth Bomber. He argues that investments in these systems was necessary for creating a 'technical grammar' or the interface that allowed these firms to relatively independently pursue their design tasks while ensuring coordination at the system level. The numerous adjustments to the product design, production process and supplier management practices that accompany modularization of work are also documented in the context of the global automotive industry (MacDuffie, 2013; Argyres and Bigelow, 2010). These organizational investments are non-trivial and emphasize the need to understand the specific work context in which investments in modularization yield high performance.

Modularization of knowledge intensive processes are feasible to the extent that projects that can be redesigned in a manner that demands fewer interactions across diverse knowledge resources. Simon (1962) characterizes such problems as low-interaction/decomposable problems, when individuals possessing distinct knowledge sets can independently apply their knowledge with a reasonable expectation that such knowledge can be recombined with the independent efforts of others. In R&D projects with tasks that are inherently routine, i.e. those that display little variability over time, modularization of the project tasks will

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[2] Although technology allows for creating digital interfaces, they can be difficult to implement. For example, Robillard (2009) suggests that API's can be unclearly specified and difficult to learn and use.

likely improve project performance. The relative stability of the knowledge and informational environment allows the project team to take advantage of knowledge specialization without worrying about whether the resulting innovations at the sub-system level can be gainfully combined at the system level (Baldwin and Clark, 2000).

In contrast, in non-routine projects modularization can hurt performance. Developing well-defined interfaces typically requires significant upfront investment in (re)designing the activities and their interactions. The greater the task variety in the project, the more difficult and expensive it becomes to design interfaces that capture this variety of interaction requirements. In addition, the relative lack of stability means that as non-routine problems are encountered there is usually a greater need for engaging in search heuristics. The specialized knowledge sets and standardized interfaces that characterize modularized work design will be inadequate for accessing more complex search strategies that may be needed to solve the non-routine problems (Ethiraj and Levinthal, 2004; Nickerson and Zenger, 2004), and may actually impede the acquisition of the requisite knowledge that promotes innovation at the systemic level (Sobrero and Roberts, 2001). Therefore,

H1a: With high interdependence, higher levels of modularization will increase performance only when task routineness is high; when task routineness is low, higher levels of modularization will lower performance.

Modularization as a coordination strategy is also expected to work well in projects where task analyzability is high. When tasks are analyzable, codifiable procedures exist to solve problems. When processes can be more explicitly documented, analysis of the sub-systems and their interactions becomes easier, which facilitates the redesigning activities into modules and codifying the interface. Such redesign permits greater task and knowledge specialization at the sub-system level. However, when task analyzability is low, the information needed to perform the task would tend to be equivocal and precise coding schemes on work activities are unlikely to be available (Daft and Weick 1984; Daft and Mcintosh 1981). When processes and their interactions cannot be documented, modularization will impede performance because the interface is unlikely to capture all the necessary information in order to correctly execute the task. Therefore, *H1b: With high interdependence, higher levels of modularization will increase performance only when task analyzability is high; when analyzability is low, higher levels of modularization will lower performance.*

Finally, informational requirements at the captive center are also impacted by the degree of familiarity of the task to the center. In general, the higher the task familiarity the better the expected overall performance, since team members' specific knowledge about aspects of their work can make them more productive (Goodman and Leyden 1991; Espinosa et al. 2007; Banker and Slaughter 2000; Reagens et al. 2005). When task familiarity is high, the project team can effectively leverage their prior knowledge to design interfaces. This is because familiarity allows the captive center team to anticipate and accommodate potential interactions in the interface design. Such knowledge is critical to effective modularization, since once interfaces are in place, the limited information transfer across modules makes it easier for teams to ignore hidden but critical interdependencies that may surface only at later stages leading to costly rework. Therefore, projects teams in captive centers that are familiar with the task and domain knowledge may benefit from a modularization strategy that enables specialization, whereas teams that are not familiar are likely to be hurt by modularization. For example, Becker and Zirpoli (2010) found that when incorporating new technologies in automobile design, too much modularity in the product design resulted in inadequate communication among engineers designing the sub-components, and in turn, results in sub-optimal performance. Therefore,

H1c: With high interdependence, higher levels of modularization will increase performance only when task familiarity is high; when task familiarity is low, higher levels of modularization will lower performance.

II. D Information Sharing

Information sharing as a coordination strategy is typically assumed to be as simple as facilitating ongoing communication between interdependent members. Though this assumption is fairly accurate in co-located projects, in the offshoring context effective information sharing is fairly difficult to achieve, and typically requires significant pre-meditated investments (Oshri et al, 2008; Aron and Singh, 2005; Mani et al, 2012). These include redrawing information boundaries, establishing communication patterns, including a common language and terminology, creating shared spaces for collaborative work, designing technology for communication and collaboration across geographies, and developing socialization processes such as shared culture and norms (Srikanth and Puranam, 2014; 2010; Mani et al. 2012; 2010; Armstrong and Cole, 2002). Mani et al. (2012) provide examples of the investments that clients and vendors make in complex technology and business process outsourcing initiatives to achieve integration of effort, such as establishing standards for communication or reducing the extent of formalized decision-making. Given the non-trivial nature of these investments in information sharing, it is not simply a fallback when modularization fails, and it becomes important to identify the work context in which the information sharing strategy yields high performance.

We noted earlier that investments in modularization work well when design problems can be broken into loosely coupled sub-problems that can be independently worked on by different teams in different locations. However, not all the work in offshore captive centers may be modularizable because the interactions between the underlying knowledge components may be unknown or evolving. In these cases, execution of the offshored task requires richer ongoing interactions between teams for problem solving (Tushman and Nadler, 1978; Puranam et al, 2012). In general, one would expect that in the circumstances in which we expect the modularization strategy to perform poorly, the information sharing strategy is likely to be associated with effective coordination and high performance.

The search for solutions to non-routine problems follows an exploratory path and demands adeptness at troubleshooting and exception handling. In turn, captive centers dealing with problems with low routineness require channels for rich communication about the problem as well as potential solutions across locations that they are interdependent with. An information sharing strategy also allows interdependent workers to share relevant knowledge in order to develop a comprehensive understanding for problem solving (Nickerson and Zenger 2004). In contrast, when problems are more routine, investments in information sharing capabilities could be an overkill as captive centers would incur the costs of implementing and maintaining costly technological resources such as conference rooms, tele-presence technologies and video servers without the corresponding benefits. With high routineness of tasks, a great deal of the work can be anticipated and planned through task design coordination without the additional need for information and knowledge sharing. Therefore,

H2a: With high interdependence, information sharing as a coordination mechanism will increase performance only when routineness is low; when routineness is high, higher levels of information sharing will lower performance.

As noted earlier, the demands on a captive center's knowledge and problem solving ability are also impacted by the analyzability of the projects they undertake. When captive centers work on projects with low task analyzability, they commit to solving problems with tacit knowledge requirements that cannot be separated into distinct sub-problems and specifiable solutions. Knowledge interactions, therefore increase, and mechanisms that allow participants to share knowledge across time and space boundaries become more valuable. Non-analyzable tasks, almost by definition, tend to cross semantic boundaries (Carlile, 1994), which require rich information channels in order to coordinate. In contrast, when captive centers work on projects with high degrees of task analyzability, it may be easier to decompose problems into independent sub-components in order to effectively coordinate work. Actors may independently pursue different task components and recombine these seamlessly into a higher-level solution. In such case, rich interactions mediated by sophisticated ICTs might be costly, redundant and detract managerial attention, thereby adversely impacting project performance. In brief, employing an information sharing strategy to coordinate offshored tasks that are analyzable may hurt overall performance. Therefore,

H2b: With high interdependence, information sharing as a coordination mechanism will increase performance only when analyzability is low; when analyzability is high, higher levels of information sharing will lower performance.

In addition to routineness and analyzability, we also expect task familiarity to influence the performance impact of information sharing. When task familiarity is low, captive centers will not have the requisite knowledge to execute the task. In such cases, investments have to be made in developing the technology infrastructure for knowledge sharing, as well as in shared language and socialization needed to sustain these efforts (Bailey and Leonardi, 2008). Absent such investments, captive centers are likely to be unable to tackle projects that are outside their sphere of expertise. On the other hand, with high task familiarity, even if the tasks are complex, captive center personnel can deliver. They are likely to be able to anticipate problems that would arise and devise plans for solving it effectively without any great need for frequent interactions with other locations. In fact, the costs associated with supporting the technology and management infrastructure needed for knowledge sharing and transfer may be unwarranted when the centers are already familiar with the tasks they encounter. In other words, familiarity with the task imposes fewer cognitive burdens on the captive center and therefore renders unnecessary tools and capabilities for rich information and knowledge sharing. Therefore,

H2c: With high interdependence, information sharing as a coordination mechanism will increase performance only when task familiarity is low; when task familiarity is high, higher levels of information sharing will lower performance.

III. Empirical Analysis

III A. Data

We test our theory in the context of offshore R&D captives – wholly owned R&D centers operated by MNCs in emerging economies such as China, India and Israel (Khurana, 2006; Oshri, 2011). Specifically, we use survey data collected from 132 captive R&D centers in India established by MNCs headquartered in developed markets. The sampling frame for our study was obtained from a census of Indian captive centers conducted by Zinnov Consulting in 2009. Zinnov's census comprises nearly 600 captive R&D centers, of which 452 were established by publicly listed MNCs. Given that 83 percent of new R&D sites established by MNCs in 2008 were in India and China, and 91 percent of new R&D staff in these firms was also located in these countries[3], we believe our results are broadly generalizable. We collected information from other sources such as Factiva to limit our sample to wholly owned subsidiaries that performed R&D or NPD work.

The data for our study were obtained through a survey of the sample captive centers. Project managers in these centers, responded in the context of large, strategic R&D projects, whose execution and delivery they were responsible for. Our unit of analysis is an offshored project, and from each firm we received only one response. The survey instrument was designed based on comprehensive reviews of the

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[3] http://www.booz.com/media/file/sb61_10408-R.pdf. Also see "Special report on innovation in emerging markets," *The Economist*, April 17, 2010.

literature and over twenty detailed interviews conducted with senior management in the captive centers. The instrument was tested with several managers to examine content validity and remove ambiguities. The insights from this pilot were used to revise the questions as well as add appropriate comments to help respondents interpret the questions. Three hundred pre-committed surveys were mailed[4], with follow-up letters five weeks later. We received a total of 132 responses that were complete in all respects.

All respondents were assured that their responses would remain confidential and results would be reported only in aggregate, thereby, addressing privacy concerns and minimizing potential bias in self-reported data. There were no systematic differences in industry, firm or task attributes between the sample and the larger population, suggesting that concerns of non-response bias were minimal (Armstrong and Overton 1970; Poppo and Zenger 2002). We also checked for the presence of common-method bias through Harman's single-factor test (Podsakoff & Organ, 1986). All variables in our study were simultaneously subject to an exploratory factor analysis, and the results of the unrotated factor solution were examined. The absence of a single factor that explained significant variance in the data suggested that common method bias did not likely impact survey responses.

Each respondent answered some general questions about the R&D subsidiary such as size, number of other subsidiaries, and product strategy. We verified some of this information using data from Zinnov's census of R&D subsidiaries. The respondents subsequently answered multiple questions pertaining to the most strategic R&D project in their center, including the underlying nature of work, coordination mechanisms used and project performance. We should emphasize that these responses were for a single specific "named" project, and not a general sense of how the average project in the center was organized. We measured the reliability of all constructs used in our analyses using Cronbach's alpha. Consistent with prior research (Nunnally and Bernstein 1994), we use an alpha of 0.7 as the cut-off value to determine reliability of the scale.

[4] A technique deployed in similar survey-based research is "to define populations and response rates based on those who will pre-commit to respond" (Poppo and Zenger 2002). The response rate for our study of approximately 44% is similar to that reported in other studies (Anderson and Narus 1990; Poppo and Zenger 2002).

These analyses were supplemented by 15 interviews with managers of captive centers in India that perform R&D or NPD work. We approached the managers of larger and well-established captives across the pharmaceuticals, IT hardware, software and semiconductor industries. The firms of some of the managers we spoke to are included in our survey, whereas others declined to participate in the survey. These interviews followed a semi-structured protocol, where we asked the managers to describe the nature of projects conducted in their centers and the coordination mechanisms used to manage them. Interviews ranged between 45 and 120 minutes, and some of them were taped with the respondents' permission. Since we had a theory guiding our research, these interviews were analyzed using a repeated readings technique to understand the nature of coordination mechanisms used and why they were chosen.

III. B Measures

Project Performance: We measure performance of the R&D project by the extent to which it meets the following: (a) cost targets; (b) quality targets; (c) technical targets; and (d) the center's expectations regarding the contribution of the project to the company. Our interviews with senior management in the captive centers as well as prior research on offshoring (Scott 2005; Puranam and Srikanth 2007) suggest that these dimensions capture the heterogeneity in motives of MNCs for establishing a captive center. Each of the categories of performance was measured along a seven-point Likert scale, where 1 represented 'strongly disagree' and 7 represented 'strongly agree'. Given the three dimensions of performance do not necessarily co-vary and to the contrary, represent tradeoffs in offshoring contexts, we use a composite measure of performance comprising the standardized sum of these items as the performance of the R&D project.

Modularization: Five items were used to measure the extent of investments in modularization of R&D activities in the captive center. The items, which were adapted from prior research (Srikanth and Puranam 2011; Mani et al. 2012), captured the effort spent on the following activities: (a) simplifying linkages between the captive center activities and tasks performed in other locations; (b) adapting the captive center activities to be executed remotely so that the need for interactions between these activities and tasks performed in other locations is minimized; (c) creating standard operating procedures so that interactions between the captive center activities and tasks performed in other locations is structured; (d) partitioning captive center activities into portions with high and low interaction components; and (e) reengineering captive center activities so that any coordination between the captive center and other locations is fully structured. These five items were measured along a seven point scale with '1' representing little or no effort, '4' representing moderate effort, and '7' representing intensive focused effort. The scale had a good fit with Cronbach's alpha of 0.89. One factor was highly explanatory of the data; the measures were averaged to form a composite score for investments in modularization. A Z-score for the variable was used in all analyses.

Information Sharing: Six items were used to assess the extent of information sharing between the captive center and other locations of the MNC. These items were adapted from prior research (Mani et al. 2012; Puranam and Gulati, 2005), and captured the extent to which each of the following pieces of information was shared: (a) quality information; (b) schedule and delivery information; (c) detailed cost information; (d) marketing information; (e) proprietary technical information; and (f) design information. These six items were measured along a seven point scale with '1' representing not shared at all, '4' representing shared moderately, and '7' representing shared very frequently. The scale had a good fit with Cronbach's alpha = 0.85. One factor was highly explanatory of the data; thus, the measures were averaged to estimate information sharing. A Z-score for the variable was used in all analyses.

Task Interdependence: We measure interdependencies in the R&D project by assessing whether: (a) changes to the work approach or direction in other locations led to changes in work on the R&D project the captive center; (b) there was a need to talk to personnel in other locations about their work on the project so they could adjust their direction. The items were adapted from prior research (Gulati et al. 1998; Srikanth and Puranam, 2011). They were measured along a seven point scale that had a satisfactory fit with Cronbach's alpha = 0.77. One factor was highly explanatory of the data; thus, the measures were averaged to measure levels of interdependence. A Z-score for the variable was used in all analyses.

Task Routineness: Measures of task routineness are well developed in the information systems literature on outsourcing (e.g. Mani et al. 2010; Tanriverdi et al. 2007). We draw on these studies to develop our measure of the routineness of activities in the R&D project. Three items measure the extent to which: (a) project workers do about the same job in the same way most of the time; (b) project tasks are the same from day-to-day; (c) work on the project is largely routine. These items, measured along a seven point scale, had a good fit with Cronbach's alpha = 0.80. One factor was highly explanatory of the data, and thus, the measures were averaged to form a composite score for routineness of project tasks. Higher values of this measure imply greater routineness. A Z-score was used in all analyses.

Task Analyzability: Measures of task analyzability too are well developed in the IS literature (e.g. Mani et al. 2010; Tanriverdi et al. 2007). We draw on these studies to measure the analyzability of tasks in the R&D project as the extent to which: (a) there was extensive documentation that described all the critical parts of the project, and (b) most of the training required to work on the project was obtained from manuals. These items had a good fit (Cronbach's alpha = 0.85). One factor was highly explanatory of the data; thus, both scores were averaged to form a composite score of analyzability. Higher values of this measure imply greater analyzability. A Z-score for the variable was used in all analyses.

Task Familiarity: We draw on prior research in IS (Reagans et al. 2005; Espinosa et al. 2007) to develop seven items that measure the degree of task familiarity in the captive center with the focal R&D work. We measured whether the R&D project: (a) involved fundamentally new concepts or principles for the captive center, (b) required new skills that the captive center did not possess, (c) required the captive center to adopt different methods and procedures, (d) required the captive center to carry out a great deal of retraining, (e) uses newly developing science/ technology know how, (f) uses radical technologies, and (g) required hiring many experts with skills that were not available in the center. Each of these items was measured along a seven-point Likert scale, where 1 represented 'strongly agree' and 7 represented 'strongly disagree'. These items had a good fit with Cronbach's alpha = 0.85. One factor was highly explanatory of the data; thus, the measures were averaged to form a composite score for levels of task familiarity. Higher values of this measure imply that the task required limited new learning and therefore was more familiar to the captive center. A Z-score for the variable was used in all analyses.

Control variables: Our performance models include a series of controls for size and age of the captive, radicalness of the innovation, product strategy of the firm, the level of autonomy enjoyed by the captive, and the extent of training received by the captive. Firm size is reflective of greater resource endowments available for coordination. Age of the captive is reflective of more mature processes that enable coordination as well as learning of the captive. Radical innovations are more difficult to coordinate. Prior research (e.g. Harzing 2002) find that the because of its standardized nature, work can be coordinated across geographic boundaries with greater ease for global product strategies. .Key structures, policies, and templates for product development, because of their similarity to R&D subsidiaries in other locations, can be replicated with greater ease. Prior research (e.g. Edwards et al. 2002, Schmid and Schurig 2003, Davis and Meyer 2004) also finds that greater autonomy to subsidiaries reduces transaction costs associated with intra-organizational coordination, enhances their ability to effectively leverage local resources and competences, and in the process, engenders learning that is valuable for adapting products developed in the home country to the host country. We also control for any training that the captive center might have received to better address coordination challenges and execute work. Finally, a large number of captives operate in technology-intensive industries that are characterized by high rates of innovation, information change, and turbulence (Mendelson and Pillai 1998). We, therefore, control for whether the sample firm operates in a technology-intensive industry. All the above measures are adapted from prior literature or developed through our field research.

We measure *firm size* as the number of full time equivalent employees that are employed in the captive center. We measure the *radicalness of the innovation* expected from the focal project using four items that estimate whether: (a) the output of the R&D project will lead to products that are difficult to replace or substitute using older technology; (b) continuous modification has been important in preventing imitation of project innovations; (c) the output represents a major technological advance; and (d) continuous development of the innovation process has been important in preventing imitation of project innovations. We measure the *product strategy* of the firm using a dummy variable that indicates whether the focal project is aimed at the global or the local market.

We estimate the *autonomy* of the captive center by examining who makes decisions in the center regarding: (a) the R&D budget; (b) the overall direction of the R&D unit's efforts; (c) which new R&D projects to pursue; (d) product design; (e) documentation standards; and (f) frequency and format of reports for R&D results. Responses were recorded on a seven-point scale with '1' representing 'Subsidiary fully autonomous' and '7' representing 'Complete control by HQ'. We estimate the *age of the captive* as the number of years elapsed since its inception as of December 2012. We also measure the *extent of training* received by the captive by examining the magnitude of effort expended in providing cultural training for its employees to better interact with employees in other locations.

Finally, we control for whether the captive center operates in a technology intensive industry. Hecker (1999) considered industries as technology intensive if employment in R&D and technology-oriented occupations was at least twice the average for all industries. These technology-intensive industries had at least 6 R&D workers per thousand workers and 76 technology-orientated workers per thousand workers. Stern (2005) points to four frequently referenced studies that have followed this approach in the literature[5]. We draw on the list of industries that have been identified by at least one of these studies as technology-intensive to classify our sample industries.

IV Results

We test the hypotheses of this study using ordinary least squares (OLS) regression models with robust standard errors. Table 2 reports summary statistics and Table 3 the pairwise correlations between the variables used in our analyses. An examination of the descriptive statistics suggests that there is sufficient variation in the key independent variables used in the regressions – attributes of the offshored task, coordination mechanisms, and interdependence. The low correlations among many of the independent variables suggest that multi-collinearity is not a significant concern in our analyses. Investments in modularization are positively correlated with interdependence and negatively correlated with task

[5] The four studies are Hecker (1999), the Organization for Economic Co-operation and Development (OECD, 1993), The Bureau of the Census, and the Milken Institute's study of "High Tech America" (DeVol and Wong, 1999).

familiarity. Indeed, prior research (e.g. Baldwin and Clark, 2000) finds that it is precisely in such situations that modularization is a very valuable coordination tool. Further, we find high correlation between interdependence and task familiarity as well as with information sharing. Finally, the high correlations between the interaction terms emphasize that it would be harder to assess their statistical significance when tested jointly.

INSERT TABLE 2 and TABLE 3 ABOUT HERE

The results for the performance regressions are presented in Tables 4, 5 and 6. Table 4 reports the baseline specifications, including the main effects (Model I) and the interactions between each of the task attributes and relational interdependence (Models II-V). The results for the controls in Model I in Table 4 are largely consistent with prior research. We find that projects that are engaging in product development and innovation for global product strategies perform better than those engaging in innovation for multi-domestic strategies. This suggests that many high performing R&D centers are working on activities that rely on firm specific advantages that are "non-location-bound" (Harzing 2001). The positive performance impact of a global product strategy is robust to most specifications in our analyses. We also find that regardless of the product strategy or nature of work performed in the R&D subsidiary, the higher the subsidiary's autonomy, the higher the project performance.

Model I in Table 4 finds that on average, task routineness has a positive and significant impact on project performance, and task familiarity and analyzability, on average, do not have a significant impact. However, we posit that the impact of these task attributes cannot be treated in isolation, independent of task interdependence and the management policies adopted in the centers. Some firms are better able to manage complex processes than other firms, and therefore, average "main effects" that do not account for these contingent relationships are difficult to interpret. Therefore, we next turn to analyzing how the level of relational interdependence modifies these effects.

Model II in Table 4 suggests that high levels of interdependence when the task is routine is associated with higher project performance. Expectedly, task routineness, because of allied well-honed processes, helps manage the demands of high interdependence between distributed locations. However, the interaction between interdependence and task analyzability does not impact project performance (model III, Table 3). Finally, we find that high levels of interdependence, when the underlying task is one that the captive is familiar with, is associated with improved performance (model IV, Table 4). This is likely because of reduced complexity - the captive center that is not taxed with acquiring new capabilities can focus on managing its interdependence with other R&D centers better. If the underlying task is unfamiliar to the captive center, managing the challenges of interdependence and acquisitions of new capabilities simultaneously is likely to overtax inventors and managers, leading to poor performance.

INSERT TABLE 4 ABOUT HERE

While we note these empirical findings, these are not the important findings from this work. Our primary interest is to identify high-performance work configurations in R&D captive centers, by examining the contingent impact of task characteristics, interdependence and coordination mechanisms employed. Specifically, we examine the impact of two coordination mechanisms – investments in modularization and extent of sharing information in managing the complexity that arises from task attributes and interdependence. Model I in Table 4 suggests that the main performance effect of information sharing is positive and significant, whereas that of modularization is negative and significant. These preliminary results suggest that in the case of complex distributed work, on average, modularization may be a detriment whereas information sharing may be more effective. We next examine 3-way interaction effects in order to answer our research question.

Table 5 reports the results for the performance impact of investments in modularization while Table 6 reports the results for the performance impact of information sharing. The fully specified equations in both tables have high explanatory power, reflected in the significant F-values and R-squares. Our first set of hypotheses (Hypotheses 1a-1c) predicts that when coordinating interdependent tasks, investments in modularization positively influence performance only when task routineness, analyzability and familiarity are all high. Model I in Table 5 shows that the interaction term between modularization, process interdependence and task routineness is positive and statistically significant, thereby, providing support Hypothesis 1a. Similarly, the interaction between modularization, process interdependence and task analyzability is positive and statistically significant in Model II in Table 5, thereby, supporting Hypothesis 1b. Model III in Table 5 shows that coefficient for the interaction term involving modularization, interdependence and task familiarity is positive but statistically insignificant.

The three-way interactions between the task attributes, interdependence and modularization can also be illustrated by plotting the relation between modularization and performance at high and low values of interdependence and the relevant task attribute (for a discussion of plotting techniques, see Aiken & West, 1991; Dawson and Richter, 2006). Given that our hypotheses pertain to high levels of interdependence, we plot the relation between modularization and performance at high and low levels of the task attributes, holding interdependence constant at high levels (Figure 1). We also report results of t-tests for differences in slopes between the curves. Such difference reflects the marginal change in the impact of modularization on performance as the process variable is changed from high to low levels at high level of interdependence. All the independent variables used in the interaction plots were standardized (i.e. centered around zero and scaled to have a standard deviation of 1).

In the case of routineness and analyzability, the interaction plots reaffirm support for Hypotheses 1a and 1b - modularization improves performance only when routineness and analyzability are high. When these task attributes are at low levels, increasing investments in modularization turns counter-productive and decreases performance. Further, the significant difference in slopes suggests that this difference in impacts between high and low levels of task routineness is significant ($p<0.05$). In the case of task familiarity, the slopes of the lines for high and low familiarity tasks indicate that modularization reduces performance in both cases. Given that the mean value for familiarity in our data was 2.75 (min=1.0 and max=7.0), it is likely that that many of the sample projects involved rather new and unfamiliar tasks and even the projects classified as 'high familiarity' relative to the rest of the sample might have had substantial newness to them. However, the difference in the two slopes is insignificant, suggesting that the impact of change in task familiarity is insignificant.

INSERT TABLE 5 ABOUT HERE

Our second set of hypotheses (Hypotheses 2a-2c) predicts that information sharing positively influence performance when task routineness, analyzability and familiarity are all low. As in the earlier case, in addition to examining the significance of the regression coefficients, we use interaction plots to examine the three-way interactions between information sharing, the task attributes and interdependence (Figure 2). Model I in Table 6 shows that the 3-way interaction term between information sharing, process interdependence and task routineness is negative as expected, but statistically insignificant. The equivalent interaction with task analyzability in Model II in Table 6 is positive but statistically insignificant. Model III in Table 6 shows that coefficient for the interaction between information sharing, interdependence, and task familiarity is negative and significant. Therefore, the regressions coefficients suggest that only Hypothesis 2c is supported. These results are consistent with the interaction plots, which show that on average, information sharing improve performance for R&D work. However, a significant difference in slopes between high and low levels of task attributes is observed only in comparing projects of low versus high familiarity. The difference in slopes for the other task variables is insignificant.

INSERT TABLE 6 ABOUT HERE

The abovementioned results, while identifying high performance work configurations, are characterized by causal ambiguity. For instance, while we theorize that when R&D work is relatively routine, investments in modularization will yield improved performance, it is also likely that modularization results in greater routinization of work that improves performance.

We used the data from the qualitative interviews that we conducted in conjunction with the survey to help us address this issue to get closer to a causal explanation. All the interviews point to captive centers choosing coordination strategies – *modularization* versus *information sharing* – based on the underlying task characteristics, i.e., handling largely routine tasks or handling well-specified and analyzable tasks, or tasks for which the captive centers had a great deal of prior knowledge. For instance, the director of strategy in a leading pharmaceutical firm commented that certain teams in the captive handled relatively routine tasks in R&D such as consumer data management for field trials including reporting of side effects from such trials, and case analyses to provide inputs for drug design. He remarked that these activities were "chunks of global projects" that were idiosyncratic to diverse global locations of the MNC and were executed in a standardized fashion across these locations. Because similar tasks were performed in several locations, the firm had designed these activities to be modular that can be seamlessly integrated into its drug development activity. For these operations, the captive team worked independently on drug research, submitted batch reports in a standardized format to other centers engaged in drug development, and had limited access to information beyond regulatory or compliance standards and protocols. The captive could not access information on how its research was utilized in drug development or any technical and strategic information on drug development. These investments in modularization were a response to the relatively routine nature of tasks in the pharmaceutical firm's captive center. For certain other projects however, such as the development of treatments for neglected tropical diseases such as malaria, tuberculosis, dengue and leprosy, the captive center provided marketing and sales insights across geographies and were highly interdependent with global teams in other locations. Modularization was not an effective response here, and significant investments in communication, coordination, work practices, and leadership were made.

Similarly, the director of operations of a leading digital advertising firm also commented on how coordination mechanisms were sensitive to the nature of tasks performed in the captive. He remarked that in the design of a comprehensive digital marketing strategy, the parent traditionally handles all client relationships and leverages the Indian center largely to build scale for relatively routine tasks such as compliance verification of digital advertisements across multiple languages. In this case, the dominant coordination strategy was modularization:

> *"the [onsite]team would interact with clients, figure out the solution to their business problem, and then tell the India team to deliver the outcome. So, the work was more modularized, where the India team was assigned separate smaller modules that could be handled and delivered independently"*

In sum, our qualitative data suggests that the choice of coordinating mechanisms is a response to underlying task characteristics, and not vice-versa. Our empirical examination alone cannot pinpoint causality, but the qualitative data suggests that it may be as we theorize.

V. Discussion and Conclusion

Recognizing the growing importance of delivering complex innovative work from globally dispersed captive centers, this study attempts to advance theoretical and practical understanding of how the coordination challenges that ensue can be better managed. The primary purpose of this study was to identify high performance configurations of task characteristics and coordination mechanisms in offshoring highly interdependent knowledge intensive work. These coordination choices determine how firms will use the power and capabilities of IT – investments in technologies that aid in modularization of the work versus in technologies that aid in greater information sharing.

We find that there are complex contingencies that have profound implications for the performance consequences of these two choices. In particular, we find investments in modularization of work across locations are ineffective when the offshored work is less routinized, less analyzable, and less familiar to the captive center. Conversely, investments in information sharing geared toward developing shared meanings have the highest impact on outcomes when the offshored work tends to be less familiar. Thus, both the nature of the offshored task and the level of interdependence between the captive center and other locations influence the relative efficacy of coordinating work through modularization versus through information sharing.

Much of the prior literature on distributed work in offshore service production has focused on standardized services such as IT and BPO processes (e.g. Aron and Singh 2005; Tanriverdi et al., 2007; Oshri et al, 2007; Srikanth and Puranam 2011; Mani et al. 2010; 2012) and on the choice between internal (hierarchies) and contractual (markets) modes of coordination. These studies concur that given the high incentive and cognitive conflicts involved in the coordination of more complex work, the latter are best organized through hierarchies. Indeed, given tighter control in vertically integrated captive centers, firms are choosing to offshore more complex work than ever before (Levina and Vaast, 2008). However, our results emphasize that even within hierarchies, cognitive conflicts persist and coordination choices explain significant heterogeneity in performance. While our study focuses on two important coordination mechanisms, future research could explore investments in specific technologies that are used to effect these modes of coordination as well as the incentive conflicts arising from problems of performance attribution for interrelated tasks whose quality is difficult to observe and verify as is the case in R&D. Such analyses are necessary to yield a more holistic picture and identify boundary decisions.

An important contribution of this study lies in the careful explication of the conditions under which choice of investments in modularization versus in information sharing yield differential performance outcomes. Although modularization is implicitly assumed as an effective strategy for exploiting the opportunities afforded by global collaboration (Mani et al. 2012) our work shows that the success of this strategy has to be evaluated based on the nature of the underlying work. As offshored work decreases in routineness, analyzability, and familiarity to the captive centers, it can no longer be safely assumed that such work is easily separable from other activities performed in disparate locations. Shrinking opportunities for coordination through modularization entail greater investments in information and knowledge sharing capabilities as the more appropriate choice for coordination. Managers should be aware of the consequences of continuing a modularization strategy in the face of offshored work that displays greater day-to-day variability, is more equivocal and less familiar to the captive centers – their efforts can be detrimental to overall performance.

This result suggests that activities that display high variability, low analyzability and low familiarity should be organized with high levels of information sharing, which is the alternative to modularity. However, our statistical analyses support only the hypotheses for familiarity. There could be two plausible explanations for this. First, it is likely that even with the kinds of transformational ICTs that modern firms use to accomplish work across time and space, tasks with very low analyzability that require high levels of implicit knowledge are simply too overwhelming in their coordination demands to be effectively offshored (Mani et al. 2013; Leonardi and Bailey 2008). Second, in our sample, perhaps there has not been adequate investment in information sharing for coordinating such activities, or perhaps these investments have not been in the appropriate technologies (Rice, 1992; Srikanth and Puranam, 2011). Future research in IS could examine how specific technologies used to enact information sharing impact performance. Leonardi and Bailey's (2008) rich case study of a large auto manufacturer that distributed its engineering work across several continents suggests that technologies such as CAD and CAE do not fully convert the tacit knowledge needed in the offshore centers into explicit, actionable knowledge, as they do not provide the requisite capabilities for articulating the assumptions necessary for building and analyzing models. In addition to exploring the variance in information richness of these technologies, future research could also analyze how various technologies such as communication technologies, knowledge management systems, and other formal and informal learning networks that are used to enact information sharing align with different types of offshored tasks to influence performance.

In this perspective, it is worthwhile remembering that firms need to choose how they are going coordinate activities in a project. This choice between modularization and information sharing needs to be done carefully, since prior research suggests that it is difficult to switch between these strategies if expected performance is not achieved. This is because both these mechanisms require specific kinds of investment in order to be effective. For instance, modularization requires significant upfront effort in mapping diverse activities in task execution and understanding the underlying patterns of interdependence, designing interfaces between organizational actors, getting buy-in for these protocols, etc. Such efforts are also accompanied by changes in organizational structure and business processes within the organization (MacDuffie, 2013; Argyres and Bigelow, 2010; Mani et al. 2010). Similarly information sharing requires investments in redrawing information boundaries and ownership, establishing communication patterns including a common language and terminology (Mani et al. 2012), creating shared spaces for collaborative work, investing in the underlying technology for communication and collaboration across geographies (Srikanth and Puranam, 2014; Kotha and Srikanth, 2013; Mani et al. 2012), and socialization processes such as shared culture and norms (Oshri, Kotlarski and Willcocks, 2009; Oshri, Van Fenema and Kotlarski, 2008). Information sharing strategy is not as easy as a telephone call on an as needed basis. This is especially true in complex technical settings such as R&D and product development and therefore, implies a degree of pre-meditation in setting up this infrastructure.

It is worthwhile noting that the issues of coordination and work design highlighted in this study are applicable to most R&D and NPD work, and much more so to work that is geographically distributed rather than work that is co-located. The ready availability of rich ongoing face-to-face communication made coordinating work in co-located settings fairly uncomplicated. However, the significant advance in ICTs has disaggregated the value chain on how interdependent knowledge intensive work is organized in the past few decades. This has led to a resurgence in the study of organization design, especially from a coordination viewpoint. Therefore, understanding high performance configuration of task characteristics and coordination mechanisms is highly salient in geographically distributed work in a way that it is not in co-located work. Whereas all distributed work is challenging, the differences in language, culture, norms, processes, and time zones make offshoring of R&D a greater challenge in organization design than work distributed within a single country. Our research question stands in particularly high relief in the offshoring setting making it a good context to identify subtle effects of organization design on task performance. In other words, whereas our findings are likely to be applicable in all distributed R&D and NPD contexts, the strength of these relationships and therefore the performance implications of inappropriate organization design are likely to be more salient in the offshoring context.

Implications of our study should be derived in light of the following limitations. The results reported here are obtained from a cross-sectional survey and as such, all the limitations of this research approach are pertinent here. First, notwithstanding the insights from the qualitative interviews, the cross-sectional nature of our data limits our ability to empirically establish causality among the relationships studied. Further, given that offshoring of knowledge work via captive centers is still an evolving work practice, a cross-sectional picture could be masking some critical insights. For example, coordination mechanisms utilized may evolve over time even for the same tasks. Thus, investments in modularization versus investments in information sharing may not be stark design choices at the start of the project. We did control for captive age in our regressions; however longitudinal studies can explore this dynamic interplay between the evolution of the offshored tasks, coordination choices and the learning in the captive center. Longitudinal studies will also be useful in exploring whether ex ante considerations of performance influence coordination choices[6].

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[6] We tested for potential endogeneity. The results of Hausman's specification test for endogeneity of modularization and information sharing indicate that OLS produces consistent estimates and is efficient. It is likely that endogeneity

The measures we use in this study are perceptual measures, and although the scales were thoroughly validated and deemed reliable, the results could be made more robust if triangulated with objective performance data. Unfortunately, the financial or innovative performance of captive centers (being wholly owned by the parent MNCs) is not reported separately in annual reports or in other publicly accessible data sources. Future studies could try to validate the performance data, perhaps through a multi-informant survey design that allows for other independent assessments of performance, such as from senior managers at the parent company who oversee the operations in the captive center.

Another limitation of our study is that we do not control for unobserved factors that may influence both the choice of investments in coordination as well as the overall performance. Indeed, a variety of firm-level characteristics such as culture, openness to technology adoption and ease of use as well as unobserved project characteristics may impact the choice variables and ensuing performance. However, since we hypothesize not about the main effects of coordination choices of firms but about their interaction with attributes of the offshored task and interdependence between the captive center and other locations, we believe that this is of lesser concern.

Despite these limitations, we believe that this study makes important theoretical and practical contributions to the literature on coordination of distributed work. Data on task characteristics and interdependencies underlying a range of R&D projects offshored to India allow us to take an early step towards understanding what drives the performance of this emerging and complex work practice. The results yield an important understanding of the value of offshored R&D and enable MNCs to define and enact a coordination strategy that positively influences innovation outcomes and competitiveness.

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does not impact our results because the constraints imposed by performance are incorporated into coordination choices over longer periods of time. However, it is important to recognize that as the performance contribution of the captive center evolves with time, the work offshored and the coordination choices to manage such work also evolve as does their relationship.

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APPENDIX: Tables and Figures

TABLE 1 – An Example of Task Attributes

Routineness (Low variety)	**Analyzability (Codifiable)**	**Familiarity (Known knowledge domain)**
YES: Captive Center (CC) carries out clinical trials for a drug, which typically involves precisely executing a standardized set of tasks.	**YES:** Stage 3 clinical trial where trial parameters are well established.	**Y:** The CC has done such clinical trials in the past for other drugs (for example, similar compounds or same therapeutic area)
		N: The CC has not done such clinical trials in the past for other drugs (for example, this is a new class of compounds or a new therapeutic area)
	NO: Stage 0/ Stage 1 clinical trial where trial parameters are not well established.	**Y:** The CC has done such clinical trials in the past for other drugs (for example, similar compounds or same therapeutic area).
		N: The CC has not done such clinical trials in the past for other drugs (for example, this is a new class of compounds or a new therapeutic area).
NO: CC carries out research in developing new drugs, which typically involves executing a large variety of tasks.	**YES:** chemical-based drug.†	**Y:** The CC has done such research before (for example, similar compounds or therapeutic area) and can draw on that knowledge.
		N: The CC has not done such research before (for example, this is a new class of compounds or a new therapeutic area).
	NO: Biologics based drug.†	**Y:** The CC has done such research before (for example, similar proteins or therapeutic area) and can draw on that knowledge.
		N: N: The CC has not done such research before (for example, this is a new class of proteins or a new therapeutic area).

†: It is generally believed that small-molecule research based on organic chemistry is more easily codified than large-molecule research based on bio-technology (Hopper and Balakrishnan, 2003).

TABLE 2 – Descriptive Statistics

Variable	Obs	Mean	Std. Dev	Min	Max
Performance	138	5.48	0.60	3.5	7.0
Size	138	334.80	474.84	11.0	2500.0
Global Project	138	0.47	0.50	0.0	1.0
Radicalness	138	4.03	0.33	3.0	5.0
Autonomy of Captive (reversed)	132	4.27	0.80	1.7	5.0
Task routineness	132	4.67	1.09	1.0	7.0
Task analyzability	138	5.75	0.84	2.0	7.0
Task familiarity	138	2.75	1.23	1.0	7.0
Task Interdependence	138	5.13	1.63	1.0	7.0
Investments in modularity	132	5.54	1.26	1.0	7.0
Information sharing	132	5.40	0.94	1.0	7.0

TABLE 3 – Correlation Table

Ti		**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**
Performance	(1)	1.00										
Size	(2)	-0.05	1.00									
Global Project	(3)	0.19*	0.06	1.00								
Radicalness	(4)	0.07	-0.07	-0.14	1.00							
Captive Control	(5)	-0.20*	0.02	0.06	-0.07	1.00						
Task Interdependence	(6)	-0.14	0.29*	-0.04	-0.10	0.20*	1.00					
Task Routineness	(7)	0.20*	0.20*	0.04	-0.08	0.12	0.33*	1.00				
Task Analyzability	(8)	-0.13	0.16	0.04	-0.17*	-0.05	0.24*	0.26*	1.00			
Task Familiarity	(9)	0.11	-0.35*	0.02	0.11	-0.17*	-0.69*	-0.35*	-0.29*	1.00		
Modularization	(10)	-0.23*	0.34*	0.03	-0.13	0.32*	0.66*	0.29*	0.43*	-0.71*	1.00	
Information Sharing	(11)	0.12	0.21*	0.03	-0.10	0.22*	0.42*	0.21*	0.15	-0.50*	0.52*	1.00

TABLE 4 – The impact of task characteristics and interdependence on project performance

	MODEL I	MODEL II	MODEL III	MODEL IV	MODEL V
Size	-0.07	-0.07	-0.07	-0.03	-0.04
	(0.09)	(0.08)	(0.09)	(0.09)	(0.08)
Global Project	0.17**	0.14*	0.17**	0.16*	0.13
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
Radicalness	0.07	0.06	0.07	0.10	0.07
	(0.08)	(0.09)	(0.08)	(0.08)	(0.08)
Captive Control	-0.21**	-0.22**	-0.21**	-0.22**	-0.23**
	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)
Information sharing	0.29***	0.25***	0.28***	0.21**	0.18*
	(0.09)	(0.09)	(0.08)	(0.10)	(0.09)
Modularization	-0.19	-0.15	-0.19	-0.20	-0.16
	(0.15)	(0.15)	(0.16)	(0.14)	(0.15)
Task Interdependence	-0.07	0.02	-0.08	-0.20	-0.11
	(0.12)	(0.12)	(0.13)	(0.12)	(0.13)
Task Routineness	0.30***	0.40***	0.30***	0.32***	0.41***
	(0.08)	(0.1)	(0.08)	(0.08)	(0.10)
Interdependence *Routineness		0.16**			0.14*
		(0.08)			(0.08)
Task Analyzability	-0.11	-0.14*	-0.11	-0.08	-0.12
	(0.08)	(0.08)	(0.08)	(0.08)	(0.09)
Interdependence * Analyzability			-0.01		-0.02
			(0.08)		(0.09)
Task Familiarity	0.01	0.03	0.01	0.09	0.11
	(0.13)	(0.13)	(0.12)	(0.14)	(0.15)
Interdependence * Familiarity				0.06**	0.14**
				(0.06)	(0.06)
Firm age	0.06	0.06	0.06	0.07*	0.06
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Inv in Training	-0.10	-0.12	-0.10	-0.06	-0.08
	(0.10)	(0.10)	(0.10)	(0.11)	(0.11)
High-tech industry	-0.19	-0.18	-0.19	-0.18	-0.17
	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
Constant	-0.08	-0.16*	0.08	0.18	0.12
	(0.18)	(0.18)	(0.18)	(0.18)	(0.18)
Observations	132	132	132	132	132
R-squared	0.30	0.32	0.30	0.32	0.34
F	7.12	6.93	6.59	7.89	6.36

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.10

TABLE 5 – Moderating effect of investments in modularization on the impact of task characteristics and interdependence on project performance

	MODEL I	MODEL II	MODEL III
Size	-0.06	-0.09	-0.03
	(0.08)	(0.10)	(0.10)
Global Project	0.11	0.19**	0.15*
	(0.07)	(0.08)	(0.10)
Radicalness	0.03	0.07	0.77
	(0.07)	(0.08)	(0.08)
Captive Control	-0.19*	-0.23**	-0.22**
	(0.10)	(0.09)	(0.10)
Task Interdependence	-0.07	-0.16	-0.23
	(0.14)	(0.13)	(0.17)
Task Routineness	0.45***	0.35***	0.30***
	(0.08)	(0.08)	(0.10)
Task Analyzability	-0.05	-0.10	-0.08
	(0.08)	(0.09)	(0.08)
Task Familiarity	0.06	0.01	0.14
	(0.13)	(0.12)	(0.17)
Modularization	-0.09	-0.01	-0.15
	(0.19)	(0.21)	(0.25)
Information Sharing	0.08	0.21**	0.24**
	(0.09)	(0.09)	(0.09)
Modular * Interdep	-0.03	0.03	0.00
	(0.07)	(0.07)	(0.12)
Interdep * Routineness	0.12		
	(0.10)		
Modular * Routineness	0.47***		
	(0.10)		
Modular * Interdep * Routineness	0.16***		
	(0.06)		
Interdep * Analyzability		0.10	
		(0.12)	
Modular * Analyzability		0.10**	
		(0.05)	
Modular * Interdep * Analyzability		0.11**	
		(0.05)	
Interdep * Familiarity			0.23*
			(0.14)
Modular * Familiarity			0.02
			(0.11)
Modular * Interdep * Familiarity			0.03
			(0.05)
Firm age	0.07*	0.07*	0.06
	(0.04)	(0.04)	(0.04)
Inv in Training	-0.02	-0.12	-0.06
	(0.12)	(0.11)	(0.11)
High-tech Industry	-0.14	-0.16	-0.18
	(0.19)	(0.03)	(0.20)
Constant	-0.07*	-0.17	0.22

	(0.19)	(0.21)	(0.22)
Observations	132	132	132
R-squared	0.40	0.34	0.33
F	8.08	7.27	6.66

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.10

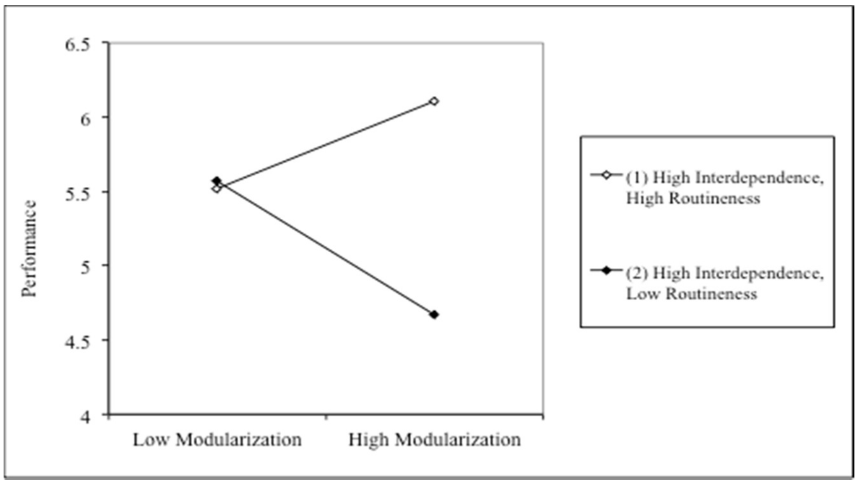
TABLE 6 – Moderating effect of information sharing on the impact of task characteristics and interdependence on project performance

	MODEL I	MODEL II	MODEL III
Size	-0.09	-0.08	-0.08
	(0.08)	(0.09)	(0.09)
Global Project	0.13	0.18**	0.11
	(0.08)	(0.08)	(0.08)
Radicalness	0.07	0.07	0.07
	(0.08)	(0.08)	(0.08)
Captive Control	-0.18*	-0.20**	-0.18**
	(0.09)	(0.09)	(0.09)
Task Interdependence	0.02	-0.05	-0.26**
	(0.12)	(0.13)	(0.13)
Task Routineness	0.33***	0.29***	0.23***
	(0.11)	(0.09)	(0.09)
Task Analyzability	-0.15*	-0.15	-0.09
	(0.08)	(0.10)	(0.08)
Task Familiarity	0.04	0.02	0.18
	(0.12)	(0.13)	(0.13)
Modularization	-0.18	-0.15	-0.08
	(0.13)	(0.15)	(0.13)
Information Sharing	0.36***	0.35***	0.60***
	(0.12)	(0.11)	(0.15)
Info Shr * Interdep	0.07	0.10	0.40***
	(0.07)	(0.06)	(0.11)
Info Shr * Routineness	0.22*		
	(0.11)		
Interdep * Routineness	0.07		
	(0.08)		
Info shr * Interdep * Routineness	-0.04		
	(0.07)		
Interdep * Analyzability		-0.01	
		(0.09)	
Info Shr * Analyzability		0.05	
		(0.15)	
Info Shr * Interdep * Analyzability		0.07	
		(0.06)	
Interdep * Familiarity			0.24***
			(0.09)
Info Shr * Familiarity			-0.18*
			(0.10)
Info Shr* Interdep * Familiarity			-0.11**
			(0.05)
Firm age	0.04	0.05	0.02
	(0.04)	(0.04)	(0.04)

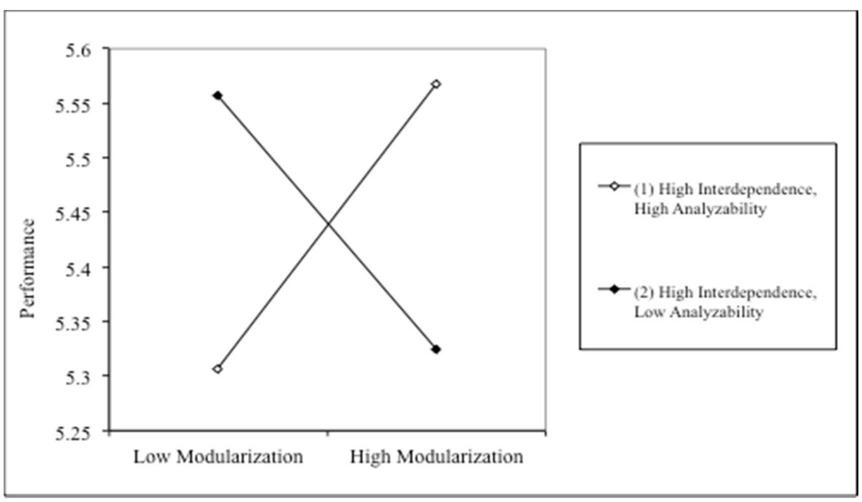
Inv in Training	-0.13	-0.10	-0.01
	(0.11)	(0.11)	(0.11)
High-tech industry	-0.11	-0.16	-0.00
	0.20	0.21	(0.20)
Constant	-0.76	-0.02	-0.06
	(0.20)	(0.20)	(0.20)
Observations	132	132	132
R-squared	0.37	0.31	0.40
F	6.93	5.74	8.57

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.10

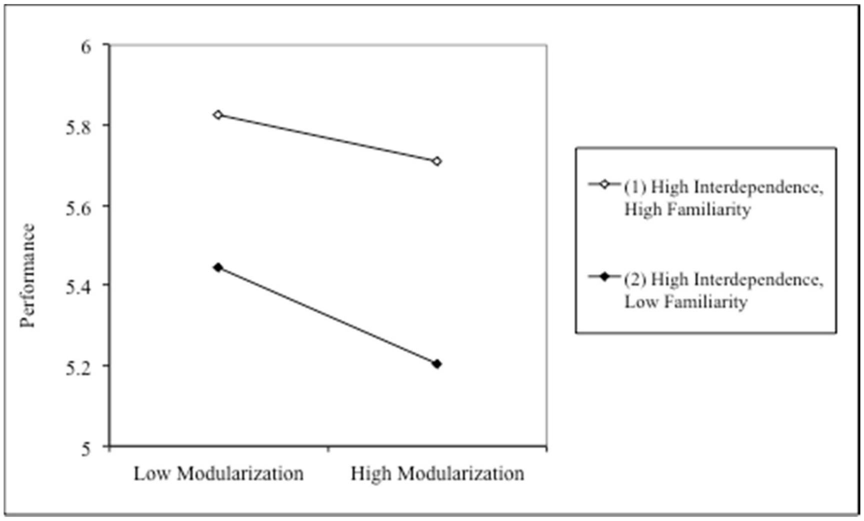
Figure 1. Interactions of Modularization with Interdependence and Task Attributes – a) Routineness; b) Analyzability; c) Familiarity



(a) t-value for test of difference between slopes (1) and (2): 4.523; p-value=0.000

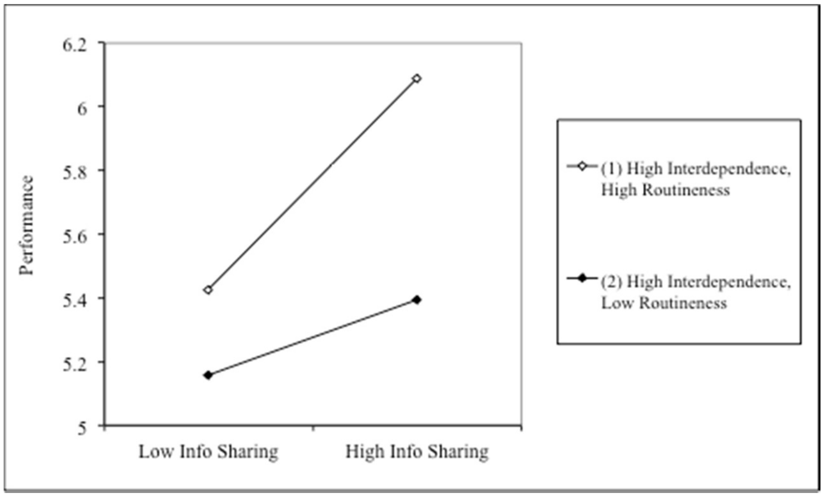


(b) t-value for test of difference between slopes (1) and (2)= 2.718; p-value =0.008

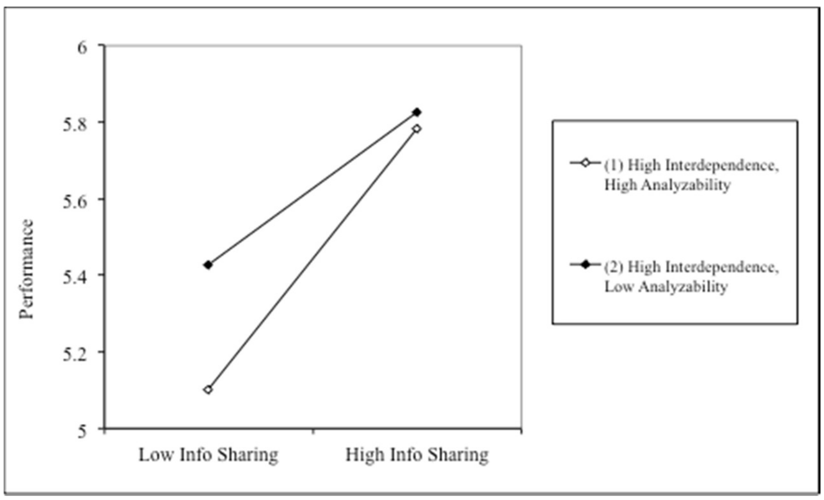


(c) t-value for test of difference between slopes (1) and (2): 0.710; p-value=0.48

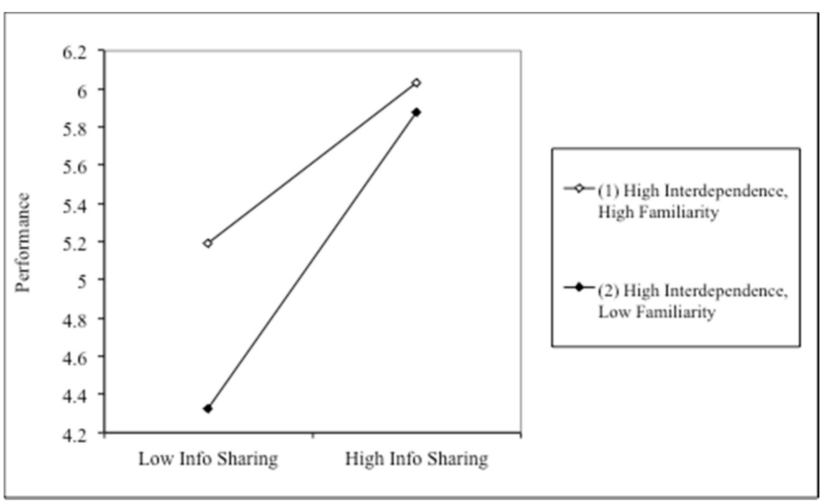
Figure 2. Interactions of Information Sharing with Interdependence and Task Attributes – a) Routineness; b) Analyzability; c) Familiarity



(a) t-value for test of difference between slopes (1) and (2): 1.023; p-value=0.307



(b) t-value for test of difference between slopes (1) and (2)= 0.578; p-value =0.564



(c) t-value for test of difference between slopes (1) and (2): -2.390; p-value=0.018