Comparative Evaluation of Efficiency across Distributed Project Organizations: A Stochastic Frontier Analysis

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December 2008

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Abstract

Efficiency in project execution is a central concern in project management. Concerns about the efficiency of project execution, such as the execution information technology and product development projects, have been exacerbated with projects being increasingly distributed across firm and geographical boundaries. The purpose of this paper is to present an econometric approach to measure project efficiency and investigate its enablers and barriers. Using stochastic frontier analysis (SFA), we measure a specific form of project efficiency called *technical efficiency*, which is defined as the ability of a project (or any productive entity) to obtain maximal attainable outputs from a given set of inputs. A technical efficiency model that includes the long-run and short-run factors to explain the variation in technical efficiency across projects is specified and estimated. The long-run factor is the choice of the type of project organization for executing a project, namely, *Collocated Insourcing, Distributed Insourcing, Outsourcing, Offshoring,* and *Offshore-Outsourcing*. The short-run factors are those related to project management, such as *risk management planning*, *agile management practices*, *face-to-face interaction*, and *employee turnover*. The empirical analysis is based on primary data collected from more than 700 projects, a mix of information technology and product development projects. Projects from 26 industries and across 65 countries are represented in the study sample. The empirical analysis results indicate that the choice of the type of project organization is associated with the technical efficiency of a project: Distributed project organizations, particularly Offshoring and Offshore-Outsourcing project organizations, exhibit significantly lower technical efficiency compared to Collocated Insourcing project organization. Further, as would be expected, employee turnover is negatively associated with technical efficiency of a project. In contrast, project management practices, such as risk management planning, agile management, and face-to-face interaction are positively associated with the technical efficiency of projects.

1. Introduction

Increasing competitive pressures are forcing firms to reconfigure organizational arrangements for executing projects, with project organizations transcending boundaries of firms and countries. Identifying the sources of project efficiencies and managing them effectively is becoming increasingly critical to successful execution of distributed projects. A recent survey by Gartner of firms engaged in outsourcing reports that the majority the companies indicated improvements in project efficiencies as their primary motivation for outsourcing (Gartner 2004). Successes in executing projects such that gains in project efficiencies are realized have not been universal (Hinds and Mortensen 2005). Recent empirical studies— namely, Duke University's CIBER/Archstone Consulting 2007 Offshoring Study[1] and Deloitte's 2007 Financial Services Offshoring Study[2] on the outsourcing and offshoring of organizational work indicate a significant gap between managerial expectations and actual outcomes. According to the Gartner's survey, 30 percent of companies did not see any cost reduction and some companies actually experienced efficiency decreases with outsourcing. In a recent study by A.T. Kearney (a management consulting firm), more than 60% of the surveyed companies seemed to fall short of their efficiency expectations (A.T. Kearney 2007). The studies cited above not only highlight the inefficiencies associated with distributed project organizations, they challenge the conventional wisdom in the practitioner literature and media reports which seems to suggest that efficiency gains are synonymous with distributed project organizations. This study is motivated by the following questions:

- *How does the efficiency of distributed project organizations compare with those that are not distributed?*
- *Within distributed project organizations, how does the efficiency of project organizations distributed across firm boundaries compare with those that are distributed across geographical boundaries?*
- *What are the key factors – namely, enablers and barriers – affecting the efficiency of a distributed project organization?*

A review of the extant literature relevant to how outsourcing and offshoring decisions are typically made provides further motivation to explore the above set of questions. Frequently, decisions related to outsourcing or offshoring of project work are made at the top management level with a strategic intent or with expectations of certain performance outcomes (Williamson 1985, Montverde and Teece 1982, Holmstrom and Milgrom 1994). Operational level issues and risk factors regarding the organization and

[1] https://offshoring.fuqua.duke.edu/pdfs/1st_highlights.pdf
[2] http://www.deloitte.com/dtt/research/0,1015,cid%253D161519,00.html

execution of distributed projects are often not well understood at the initial stages of the projects, leading to considerable "fire-fighting" and "compression" of project activities downstream, and poor resource utilization during the project execution phase (Fine and Whitney 1996, Anderson and Parker 2002, Novak and Eppinger 2002). Identifying the enablers and barriers of project efficiencies *ex ante* is, therefore, imperative for successful execution of distributed projects.

The study of project efficiency presents an interesting challenge from the standpoint of both analytical and empirical research. While a few projects are efficient in making use of their input resources and meeting their output goals, a significantly large number of projects are inefficient in realizing the output goals. Yet, as Nelson (1982) observes, deterministic induced-invention models frequently specify project capabilities as a set of isoquants or set of points on the invention possibility frontier that can be achieved for a given outlay of project inputs. Thus, an important question of "why the frontier is the way it is tends to be ignored" (p. 454). Similarly, standard econometric models for project evaluation have typically ignored heterogeneity among projects with respect to resource utilization and made an assumption that projects are operating on an efficiency frontier, i.e., are fully efficient in their use of input resources. Such an assumption, in general, is rarely reflective of most productive entities (Coelli et al. 2005).

However, in recent years, econometric advances on the estimation of stochastic frontier production functions (Battese and Coelli 1995, Kumbhakar and Lovell 2000) have opened up opportunities for researchers to examine the determinants of technical efficiency of productive entities. The Stochastic Frontier Analysis (SFA) approach, therefore, serves as the foundation in this study to specify and estimate the sources of inter-project differences in efficiency. Specifically, the specification and estimation of project efficiency is in the form of technical efficiency[3], defined as the ability of a project (or any productive entity) to obtain maximal attainable outputs from a given set of inputs (Farrell 1957). Following the measurement of technical efficiency, we specify an econometric model that includes the long-run and short-run factors to explain the variation in technical efficiency across projects.

[3] Besides technical efficiency, Farell (1957) proposed that the efficiency of any productive entity is characterized by the degree of its *allocative efficiency*. Allocative efficiency measures the maximum output for a given level of inputs at a fixed price. Thus, allocative efficiency determines whether production inputs are used in proportions that ensure maximum output at minimum input prices. Since input prices are generally difficult to quantify for most productive entities and are not easily obtainable (Greene et al. 1997), we focus primarily on examining the technical efficiency of projects in this study.

Project organization plays a central role in influencing information processing capabilities of a project. As project organizations become increasingly distributed whereby a project is simultaneously distributed across multiple boundaries, such as firm boundaries and geographical boundaries, the information processing challenges during project execution increase. Sustaining superior information processing capability in a project is critical to the day-to-day project execution, and provides the underlying mechanism for the efficient conversion of input resources into project outputs. Thus, it can be argued that factors that affect a project team's ability to coordinate and collaborate effectively are also likely to affect its technical efficiency. In this study, we first examine whether systematic differences in technical efficiency across projects can be explained by their choice of project organization type[4] (namely, *Collocated Insourcing*, *Distributed Insourcing*, *Outsourcing*, *Offshoring* and *Offshore-Outsourcing)*. Next, we investigate how project management factors such as *risk management planning*, *agile management practices*, *face-to-face interaction* (between a project client and a project team), and *employee turnover* affect the technical efficiency of a project.

Taken together, this study goes beyond earlier studies on project efficiency which have been mostly diagnostic in nature and focused mainly on benchmarking projects with respect to the efficient frontier, by examining both factors related to project organization and project management that have the potential to impact the technical efficiency of a project. According to Kamien and Schwartz (1975, p. 6), while the evaluation of a project is based, in part, on the characteristics of the project's inputs, such as budgetary allocation and size of the project team, very often the transformation of inputs to outputs may be facilitated (or hampered) by other factors relating to the management of the project. Consequently, a goal of this study is to identify what such factors are.

The empirical analysis is conducted using primary data collected from a large sample of information technology and product development projects across the five types of project organization: Collocated Insourcing, Distributed Insourcing, Outsourcing, Offshoring and Offshore-Outsourcing and spanning more than 26 industries. The results indicate that the choice of the type of project organization is associated with the technical efficiency of a project: Distributed project organizations, particularly Offshoring and Offshore-Outsourcing project organizations, exhibit significantly lower technical

[4] The term project organization, as used in this study, simply refers to the organizational structure of a project. It should not be confused with the term project management organization/office (PMO) which refers to a department or group within an organization that defines and maintains the standards of process related to project management.

efficiency compared to Collocated Insourcing project organization. Further, as would be expected, employee turnover is negatively associated with technical efficiency of a project. In contrast, project management practices, such as risk management planning, agile management, and face-to-face interaction are positively associated with the technical efficiency of projects.

The remainder of the paper is organized as follows. Section 2 discusses the methodology of stochastic frontier analysis for evaluating the technical efficiency of projects. Section 3 examines the various organizational and managerial level antecedents of technical efficiency in a project and derives a set of testable hypotheses. Section 4 describes the procedure involved in collecting primary data for this study and the overall characteristics of the study sample. Section 5 presents the results of the empirical analysis. Section 6 contains a discussion of the study's findings. Section 7 is the conclusion section where the study's contributions, limitations and directions for future research are spelled out.

2. Stochastic Frontier Analysis (SFA)

Traditionally, the production function for a project is represented as follows:

$$Y_i = f(X_{i;}\ \beta) + \varepsilon$$

where, Y_i is the observed scalar output of a project i, i=1, 2, 3,……I, X_i is a vector of N inputs used in the project i, $f(X_{i;}\ \beta)$ is the production frontier, and β is a vector of technology parameters to be estimated, and ε represents the unobserved random error in the function. One problem with this traditional approach is that conceptually, the production function embodies the trade-offs faced by an efficient project that utilizes best practice methods. However, most projects are not fully efficient in their use of inputs. This limitation motivated the development of stochastic production function (Aigner et al. 1977; Meeusen and van der Broeck 1977). A stochastic production function explicitly recognizes the heterogeneity across projects, rather than assuming it away, and can be estimated to identify the efficiency frontier and evaluate the projects relative to the efficiency frontier. Thus, a stochastic production function makes it possible to separate random errors from systematic inefficiency by decomposing the error term in such a production function. As Figure 1 illustrates, the deviation of a certain Project A from the efficiency frontier is composed of a random error component and a systematic technical efficiency component.

The stochastic *production function* without the random error component can be written as follows:

$$Y_i = f(X_{i;}\ \beta)\ .\ TE_i\ .\ \exp(V_i)$$

where TE_i denotes the technical efficiency of a project and is defined as the ratio of observed output to maximum feasible output. $TE_i = 1$ shows that the *i-th* project obtains the maximum feasible output, while $TE_i < 1$ provides a measure of the shortfall of the observed output from maximum feasible output. A stochastic component that describes random shocks affecting the production process is added. These shocks are not directly attributable to the transformation process converting a project's inputs to outputs. These shocks may be on account of macroeconomic cycles or plain luck. We denote the random effects with $\exp(V_i)$. We assume that each project faces a different shock, but the shocks are random and can be described by a common distribution.

------------------ Insert Figure 1 about here ------------------

We assume that TE_i is also a stochastic variable with a specific distribution function common to all projects. We can write it as an exponential function, $TE_i = \exp(U_i)$, where $U_i \geq 0$, since we required $TE_i \leq 1$. Now, if we also assume that $f(X_{i;}\ \beta)$ takes the log-linear Cobb-Douglas form, the *technical efficiency* function can be written as:

$$\ln Y_i = \beta + \sum \beta_n \ln X_{ni} + V_i - U_i$$

where V_i is the "noise" component, which we will almost always consider as a two-sided normally distributed variable, and U_i is the non-negative technical efficiency component. A common and parsimonious assumption in the stochastic frontier literature is that U_i is independently and identically distributed as a half-normal distribution with unknown variance σ_u. The half-normal distribution has often been substituted in favor of a less-restrictive assumption such as a non-negative truncated normal distribution or an exponential distribution of U_i . In this study, we use Battese and Coelli (1995) method for parameterizing the technical efficiency component, by specifying U_i as a function of additional, project-specific variables as shown below:

$$U_i = Z_i\delta + W_i$$

where Z_i is a vector of explanatory variables, such as those proposed later in our study. Here, δ is a vector of unknown parameters to be estimated and W_i is an unobservable random variable.

3. Antecedents of Technical Efficiency

3.1 Project Organization Types

As shown in Figure 2, we specify a two-by-two classification scheme to identify the various ways in which projects can be organized. This classification scheme is based on two key dimensions: (i) one dimension representing the geographical distribution of project organizations within and between national boundaries, and (ii) the second dimension representing the distribution of project organization within and between firm boundaries. Four distinct project organization types emerge from this two-by-two classification scheme: Insourcing, Outsourcing, Offshoring and Offshore-Outsourcing. A third dimension that represents the geographic distribution of project organization within and across cities is nested within the vertical axis to further classify *Insourcing* into two sub-types: Collocated Insourcing and Distributed Insourcing. Each of these types of project organization involves transactions between two groups of stakeholders: a *project client* and the *project team*. A project client typically assigns or contracts project tasks to a project team, and these two groups of stakeholders can be a part of the same firm or different firms, e.g., a client firm and a vendor firm. We define the different types of project organizations below. Each of these project organization types are defined below.

- **Collocated Insourcing:** A firm assigns project tasks to a collocated in-house team. An illustrative example is the design of Motorola's "Razr" phone.

- **Distributed Insourcing:** A firm assigns project tasks to its division or unit in a different city but within the same country. An illustrative example is Phoenix International, a subsidiary of John Deere, working with its agriculture equipment manufacturing division on new product development. Phoenix International is based in Fargo, North Dakota, while John Deere's agriculture equipment manufacturing division is based in Moline, Illinois.

- **Outsourcing:** A user or client firm contracts project tasks to a vendor firm in the same country. An illustrative example is U.S. firm Lucent Technologies, a client firm, contracting with Borland Inc., a vendor firm also based in the U.S., to develop automatic testing equipment.
- **Offshoring:** A user or client firm assigns project tasks to its division or unit in a different country. An illustrative example is the Microsoft corporate R&D group based in Redmond, Washington collaborating with Microsoft's India Development Center on new software development.

- **Offshore-Outsourcing:** A user or client firm contracts project tasks to a vendor firm in a different country. An illustrative example is Aviva, a U.K.-based client firm that is a leading provider of insurance products, contracting with Tata Consulting Services, a vendor firm based in India, for the development of software for partner management system.

------------------ Insert Figure 2 about here ------------------

The organization of a project plays a central role in affecting the extent to which coordination between the project client and the project team is carried out effectively. Information technology and product development projects, the empirical context of this study, typically involve uncertain environments along with ever-changing social constructions (Tsoukas 1996), and require collective action from both the project client and the project team to mutually define and address uncertainties (Galbraith 1973, Tushman and Nadler 1978). For example, both project client and project team will need to agree on a common definition of what they are doing, plan how to hand off components of the work expeditiously, and in general, mesh the activities of the team. Project team members may often need to communicate and convince project client members of their views about certain project tasks and their proper design, and possibly renegotiate these views (Wheelwright and Clark, 1992). Thus, if project team members and project client members are physically proximate, both sides can work together swiftly toward resolving technical issues that continually arise during project execution.

The distribution of a project's tasks across different locations—by moving from a Collocated Insourcing project organization toward one of the distributed project organizations—Distributed Insourcing, Outsourcing, Offshoring, or Offshore-Outsourcing systematically extends the horizontal boundaries of a project and undermines the functional integration of project tasks. Differences in organizational culture and/or national culture coupled with increased geographical distance between the project client and the project team inhibits real time information exchange and contributes to the difficulty in information processing. Further, since both a project client and the project team each possess distinct and unique task-related information (i.e., functional/business specification and technical information, respectively), the risk that each side may fail to share or heed uniquely held information is high, especially in distributed project organizations (Crampton 2001). While each side may attempt to correct or prevent these failures, they may do so by transmitting larger than required volumes of information making the information exchange process arduous, time-consuming and inefficient (Hightower and Sayeed 1995). Given that coordination between a project client and the project team is central to the transformation of project inputs into outputs, inefficiency in information processing is likely to create inefficiencies in the input-output transformation process (Tushman and Katz 1980). Taken together, the above arguments suggest that increased inefficiency of information processing in distributed project organizations compared to Collocated Insourcing project organization makes them inefficient in utilizing project inputs. Therefore, we posit the following hypothesis:

> **HYPOTHESIS 1:** *Technical efficiency of distributed project organizations is less than that of Collocated Insourcing project organizations.*

3.2 Face-to-Face Interaction

As noted earlier, technology projects are characterized by uncertain environments and require collective action from both a project client and the project team to mutually define and address uncertainties. A key determinant of the efficiency of such collective action is the medium through which information sharing takes place between a project client and the project team. While collective action is typically achieved in most teams on a daily basis through technology use, such a medium is rarely efficient when it comes to exchange of tacit project requirements or in the resolution of relationship conflict issues between the project client and the project team. Studies comparing face-to-face communication with technology mediated communication in distributed teams have noted that the information exchange process was not only less complete and biased in distributed teams (Hightower and Sayeed 1995, 1996, Hollingshead 1996), but also was less efficient and proceeded at a slower rate (Lebie et al. 1996, Strauss 1997, Strauss and McGrath 1997). Frequent and timely face-to–face communication between a project team and the project client can go a long way towards addressing such problems, helping them to revisit their assumptions and transform mutual understanding of project tasks (Kirkman et al. 2004, Hinds and Mortensen 2005). In a study of the use of new machines in a factory, Tyre and von Hippel (1997) observed that engineers had trouble resolving equipment problems over the phone because engineers needed to "see for themselves" the technology in context. Pointing out to the potential benefits of face-to-face communication in resolving project conflicts and reducing rework, Armstrong and Cole (2002, p. 172-173) comment, "A manager could walk across the hall, "nip it in the bud," and solve the problem quickly. Over distance, the issues were likely to get dropped and go unresolved, contributing to a slow buildup in aggravation." Face-to-face, communication can also be beneficial in breaking down functional silos and unique site cultures that develop across a project client and the project team employees, and which can hamper the progress of a project. Based on the above arguments, we propose the following hypothesis:

> **HYPOTHESIS 2:** *Face-to-face interaction is positively associated with the technical efficiency of a project.*

3.3 Agile Project Management

Traditional project management assumes that events affecting the project are predictable and that a project's technical and business requirements are well understood. In addition, with traditional project management, once a phase is complete, it is assumed that it will not be revisited (Wysocki 2006). The strengths of this approach are that it lays out the steps for development and stresses the importance of requirements. The limitations are that projects rarely follow the sequential flow, and project clients usually find it difficult to completely state all requirements early in the project (Hass 2007, Karlstrom and Runeson 2005).

Consequently, the role of agile project management practices are being increasingly stressed as a way of achieving fast responsiveness to changing project requirements. Agile project management is a highly iterative and incremental process, where a project team and the project client work together actively to understand project requirements, identify what project activities needs to be executed, and prioritize functionality (Chin 2004). Again, this differs from the traditional approach in that the amount of time is invested in planning and creating requirements documentation during the initial stages of the project is considerably less (Augustine et al. 2005). The notion that a project team pursues agile project management practices during project execution also implies considerable effort on the part of the project team in identifying and prioritizing project client requirements and project tasks based on business value (Lee et al. 2006). This, in turn, leads to a prioritized and systematic resource deployment strategy that improves resource utilization and targets "bottlenecks" in a timely fashion. Further, given that agile project management involves continuous and frequent evaluation of requirement changes initiated by a project client, the chances of discovering rework activities downstream are considerably reduced (Augustine et al. 2005). The following quote highlights the usefulness of agile project management practices in reducing rework:

> It's easy for separate teams to plow forward, usually under tremendous pressure from looming deadlines. They operate under the false assumption that if they can simply reach the final feature destination, they can quickly pull things together toward the end of a project… As individual modules are pulled together, common issues that surface include degradation of overall system performance, incorrect levels of behavioral granularity provided by system modules, and transactional incompatibilities. More frequent integration brings many of these issues to the forefront earlier in the project. (www.agilejournal.com)

Since rework in information technology and product development projects lead to inefficient utilization of project resources (Cooper 1993), reducing the extent of project rework through agile project management practices can be a useful method for improving technical efficiency of projects. Based on the above arguments, we propose the following hypothesis:

> **HYPOTHESIS 3:** *Agile project management is positively associated with the technical efficiency of a project.*

3.4 Risk Management Planning

> At the point when the amount at stake is the highest, usually during the later part of the life cycle when project execution takes place, the corresponding level of risk, ideally, should be low. In reality, however, this is not always the case and as a result, time and cost objectives are compromised. The key to efficiency is to reduce the occurrence of either the risk itself or reduce the impact of a risk. (www.isixsigma.com)

Unforeseen situations and uncertainties are intrinsic to most information technology and product development projects. Project risks can arise from a multitude of factors — e.g., unrealistic schedules and budgets, continuous requirement changes, lack of relevant knowledge and employee turnover. Risk management planning measures the extent to which potential risks to a project are identified at the beginning of the project, factored into requirements estimates and managed throughout the course of the project.

The importance of identifying and planning for anticipated risks early in a project has been well discussed in past studies (Loch et al. 2006, Lyytinen et al. 1998, Barki 1993). For example, Barki (1993), in a survey of information technology managers, found that that the ability to shape a project (in terms of internal integration, user participation, and formal planning) to fit its risk exposure influences the ability of the project to meet budget constraints and produce quality results. The advantages of risk management planning are that it helps the project personnel focus on many aspects of a problematic situation — i.e., it emphasizes potential causes of failures, helps link potential threats to possible actions, and facilitates a shared perception of the project among its participants (Lyytinen et al. 1998). This, in turn, helps to minimize conflict among project team members and reduces the amount of rework in a project during the later stages of a project leading to a more efficient use of project resources (Loch et al. 2006). Besides, reducing rework, managing risks through planned experimentation and testing can also prevent unnecessary flexibility in deployment of project resources (Sommer et al. 2007, Browning et al. 2002), thereby reducing inefficiencies in project execution. We, therefore, propose the following hypothesis:

> **HYPOTHESIS 4:** *Risk management planning is positively associated with the technical efficiency of a project.*

3.5 Employee Turnover

The study of employee turnover in organizations has been a subject of considerable research in the management literature (Ton and Huckman 2008, Glebbeeck and Bax 2004). Although most studies consider employee turnover as a problematic issue and have looked at its drivers**,** the nature of its performance impact is not well understood. Many studies have argued that employee turnover has a negative effect on operating performance due to the disruption of existing routines (Dalton and Todor 1979, Bluedorn 1982) or the loss of employee accumulated experience, others have suggested that firms may benefit from the innovative thinking or increased motivation that new workers bring to the job (Abelson and Baysinger 1984, Mowday et al. 1982, Staw 1980). Notwithstanding the ambiguity regarding the performance impact of turnover, employee turnover has a negative impact on the overall efficiency of resource utilization in a project, as it disrupts the progress of a project in many ways (Sterman 1994). First, when an employee gives notice for resignation or receives notice for termination of employment, he or she is likely to lose focus and become less productive. Further, during the transition time, the departing employee is less likely to take on important or challenging tasks or become involved in consequential decision making activities. In many cases, the workloads of remaining project team members may increase to offset the vacant position. Second, the process of finding a suitable replacement for those leaving a project midway is a time consuming process as suitable replacements are less likely to be found immediately in the event of the exit of a team member from a project. Even if a suitable replacement employee is found, there is an initial "set-up cost" involved – i.e., the replacement team members is likely to take some time to familiarize with the project environment and task details (Osterman 1987). Hiring a new employee also affects the productivity of supervisors and peers who must spend time helping their new team member adjust (Mowday et al. 1982). Taken together, the above arguments call to attention the disruptive effects of employee turnover during project execution. Therefore, we posit the following hypothesis:

> **HYPOTHESIS 5:** *Employee turnover is negatively associated with the technical efficiency of a project.*

4. Research Design

4.1 Sampling Frame

We followed a systematic and rigorous procedure of collecting primary data by designing and implementing a web survey. A preliminary version of the survey instrument was designed and pretested among three university researchers and two practitioners to assess content validity and clarity of the items in the questionnaire. Following this process, another round of pre-testing was conducted by sending a web-based version of the survey instrument to members of two professional project management associations: PMHUB (www.pmhub.net) and Project Management Institute's (PMI) local chapter at Pune, India.[5] This round of pre-testing allowed us to test the web-based version of the survey in conditions that would be similar to those in an actual survey implementation. Overall, the two rounds of

[5] Both PMHUB and PMI (www.pmi.org) are well recognized professional associations within the project management community that serve as a platform to project management professionals for sharing ideas and experiences, accessing industry information, attending seminars and workshops, increasing professional exposure through networking, and gaining leadership experience.

pre-testing helped us gauge the initial reactions to the survey and identify survey questions that were confusing and prone to misinterpretation by respondents. Specific aspects of the survey, such as item non-response, survey dropouts and the time taken to answer the questionnaire, were assessed and modifications were made to the content and the organization of the survey to improve the survey-taking experience. The final version of the web survey was e-mailed to the members of two specific interest groups within the PMI: (i) the PMI–Information Systems Specific Interest Group (PMI–ISSIG) and (ii) the PMI-New Product Development Specific Interest Group (PMI-NPDSIG). The "specific interest groups" (SIG's) are PMI subgroups that promote exchange of knowledge among PMI members concerning the application of project management practices, issues and challenges in specific contexts. The PMI-ISSIG has the largest membership within all specific interest groups of PMI, serving a broad range of industries in project management for the information systems sector. Two follow-up reminders sent approximately one week and four weeks apart from the date of the first mailing led to a total of 675 usable responses from this sampling group, representing a response rate of approximately 6%. For the PMI-NPDSIG, a professional association of product development professionals, three follow-up reminders were sent out approximately two weeks apart from one another from the date of the first mailing. A total of 155 usable responses were received from this sampling group, representing a response rate of approximately 13%.

This response rate noted above is lower than the typical response rates for survey research for the following reasons: First, the sampling frame of the PMI-ISSIG consists of many members (project management professionals) who have little or no experience of working on any form of distributed project organizations, and are less likely to respond to our survey. Tanriverdi et al. (2007) point out to the risks of using such sampling frames in the early stages of an emerging phenomenon. Second, the large size of the sampling frame itself is a major factor in lowering response rates. Larger sampling frames are difficult to manage, lack cohesiveness among members, and have the potential for errors in terms of invalid/bouncing e-mail addresses. While, simply limiting the size of the sampling frame may have increased the response rate (Dillman 2000), the risk of not obtaining sufficiently large representations of the various forms of distributed project organizations would have been considerably high. Third, it is very likely that surveys with similar focus have been mailed to this sampling frame in the past, leading to survey fatigue for the membership.

To check for the presence of non-response bias and potential differences across the two sampling groups, we use the extrapolation method proposed by Armstrong and Overton (1977). This method involves classifying the sample into groups of early and late respondents, and performing a series of statistical comparisons for demographic variables to identify differences across the respondent groups. The underlying assumption in applying this method is that the late respondents are similar to non-respondents as their responses are obtained after multiple contacts. Using this procedure, data from each sampling group was split into two sub-samples: the first sub-sample representing those responses obtained after the first contact and the second sub-sample corresponding to responses obtained after sending reminder mails. Statistical t-tests performed across early and late responders in each sampling group based on demographic variables, did not reveal and significant differences. Non-response bias therefore, was not a problem with the data. Further, tests on demographic differences and project performance outcomes across the two sampling groups also did not indicate any significant differences. The two sampling groups were, therefore, combined to yield a total sample of 830 technology projects for conducting the analysis in this study.

4.2 Sample Characteristics

Across the total sample of 830 technology projects, the distribution of the five project organization types were as follows: 38.6% (320) projects had Collocated Insourcing project organization, 16.1% (134) had Distributed Insourcing project organization, 20.2% (168) had Outsourcing project organization, 8.6% (71) had Offshoring project organization and the remaining 16.5% (137) had Offshore-Outsourcing project organization. Regarding the respondent profile, approximately 72% of the respondents were project managers, 13% were more senior level managers such as a project sponsor, program manager or a portfolio manager, and the remaining 14% respondents were either team members or held specialist roles within a project such as a technical lead, a quality assurance or a business analyst. Respondents were also asked to indicate their affiliation with respect to the project from among three choices: project team/vendor firm, project client/client firm or external consultant. Nearly 57% of the respondents were affiliated with the project team/vendor firm, 30% of the respondents were affiliated with project client/client firm while the remaining 13% of the respondents were affiliated with the external consultant. The average total work experience of respondents was 21.2 years, out of which an average of 11.5 years were spent in a project management role. With respect to the project characteristics, the average project team size was 28 members, and the sample of projects fell into three main categories:

- Hardware – Hardware related projects; projects in this category involve development of hardware, or software that interfaces with hardware, i.e. physical product development, system software development or embedded software development (16% of the total sample),
- Software – Application software development projects (72% of the total sample), and
- Infrastructure – Enterprise IT infrastructure development projects (12% of the total sample).

By way of geographical location, a large majority of the project client/client firms were located in the North American continent. Across the sample, nearly 75% of the projects had their project client/client firm located in North America whereas the percentage of European and Asian project clients/client firms came a distant second and third with only 8% and 6% representation, respectively. In terms of country location, USA had the highest representation of project clients/client firms at 65% of the total sample. Among projects which spanned country boundaries (Offshoring and Offshore-Outsourcing projects), a majority were carried out by project teams/vendor firms located in *t*he Asian continent; 65% of the sample of Offshoring and Offshore-Outsourcing projects are carried out by project teams/vendor in Asia; while North America ca*m*e a distant second at 17%.of the sample. In terms of country location, nearly 56% of the total sample of Offshoring and Offshore-Outsourcing projects are carried out in India.

4.3 Variables and Model Specification

The stochastic frontier analysis (SFA) requires the specification and estimation of two models: (i) the stochastic production function, which models the project output variable as a function of project input variables, technical efficiency, and the random error component, and (ii) the technical efficiency function, which models the various sources of efficiency. In this section, we identify the variables for each model and provide details regarding their measurement. Table 1 lists the key variables (and their underlying measurement items) in the production function and the technical efficiency function.

------------------ Insert Table 1 about here ------------------

4.3.1 Output Variable in the Production Function

The output variable in the stochastic production function is *Project Performance*, an index (Cronbach's $\alpha = 0.90$) derived from the mean of five items that captures the outcomes of a project on various performance dimensions such as adherence to schedule, budget, quality, technical performance, and overall satisfaction. These dimensions have been widely used in the product development literature and provide a holistic assessment of project outcomes (Gerwin and Barrowman 2002, Krishnan and Ulrich

2001). Responses across each item was recorded on a 7-point Likert scale (1 = Significantly Worse, 7 = Significantly Better).

$$Project\ Performance_i = \frac{Adherence\ to\ Schedule_i + Adherence\ to\ Budget_i + Adherence\ to\ Quality_i + Technical\ Performance_i + Overall\ Satisfaction_i}{5}$$

4.3.2 Input Variables in the Production Function

The following input variables are included in the production function:

Team Size: Team size (*TeamSize*) is measured as the total number of employees who participated in the project. This measure is indicative of the input that goes into a project in the form of manpower, and is also indicative of the resource availability in a project.

Project Duration: Project duration (*Duration*) measures the total duration of a project in months, and is also another indicator of the manpower input in a project.

Project Budget: Project budget (*Budget*) is measured as an ordinal categorical variable that represents the total budgetary allocation in a project (1= *Budget* < \$10,000, 2 = *Budget* between \$10,000 and \$50,000, 3 = *Budget* between \$50,000 and \$100,000, 4 = *Budget* between \$100,000 and \$250,000, 5= *Budget* between \$250,000 and \$500,000, 6 = *Budget* between \$500,000 and \$1 Million, and 7 = *Budget* > \$1 Million).

Past Experience: We also control for the past experience (*PastExperience*) of the project team in handling similar projects as this could be a critical factor in affecting project performance (Haas 2006). Four items (Cronbach's $\alpha = 0.75$) were used to capture the experience of project team in working on projects that were similar to this project in terms of project organization type, scope/size and project client requirements. The responses for this construct were recorded on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Project Uncertainty: Both technological uncertainty (*TECHUNC*) and requirements uncertainty (*RUUNC*) constructs were each measured on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree) using four items adapted from Nidumolu (1995). The question items for technological uncertainty (Cronbach's $\alpha = 0.76$) tapped into the extent of team members understanding of a project's technical requirements and their familiarity with the technology used in the project. The question items reflecting requirements uncertainty (Cronbach's $\alpha = 0.85$) measured the degree of stability of project client requirements at various stages in the project. Architectural uncertainty (*ARCHUNC*) for a project is measured using three items (Cronbach's $\alpha = 0.76$) that measure the extent of difficulty involved in decomposing a project into individual task modules, and in clearly identifying the interdependencies across the task modules. The responses across each item were recorded on a 5-point Likert scales (1 = Strongly Disagree, 5 = Strongly Agree).

4.3.3 Control Variables in the Production Function

In addition, we also control for variation across projects due to their different characteristics, which could potentially explain performance differences. We control for several such project characteristics in our analysis. The different project categories in the sample (Hardware, Software and Infrastructure), each place different information requirements and challenges for team members, and could potentially confound the measure of project performance. Following past studies that have controlled for the effect of project type on performance (e.g., Atuahene-Gima 2003, Bell and Kozlowski 2004), we created two dummy variables (*Hardware* = 1 for projects in the Hardware category, and 0 otherwise; *Software* = 1 for projects in the Software category, and 0 otherwise) and entered them into our analysis. We also controlled for heterogeneity in industry type in our sample by including dummy control variables for selected industries that have high representation in the sample[6]: (*InformationTechnology* = 1 for projects in information technology industry, and 0 otherwise; *Banking* = 1 for projects in banking industry, and 0 otherwise; *Insurance* = 1 for projects in insurance industry, and 0 otherwise; *HealthCare* = 1 for projects in healthcare industry, and 0 otherwise; *Manufacturing* = 1 for projects in manufacturing industry, and 0 otherwise). In addition, given that the majority of the project teams were located in North American continent, we control for project team location by using a dummy variable (*NorthAmerica* = 1 when the project team is located in North America, and 0 otherwise).

As the measure for the dependent variable, project performance, could be affected by the views of the respondent, we also control for heterogeneity among respondents using variables that represent:

- Years of project management experience of the respondent: We include the natural logarithm of this variable (ln(*PmRole*)) in our analysis.
- Respondent's role in the project: Two dummy variables were created to represent three respondent roles (*ProjectManager* = 1 for project manager, and 0 otherwise; *SeniorManager* = 1 for senior level managers, and 0 otherwise).
- Respondent's affiliation with respect to the project: Two dummy variables were created to represent three categories (*Client* = 1 for project client/client firm, *ProjectTeam* = 1 for project team and 0 otherwise;

[6] Although the sample of 830 technology projects was drawn from more than 26 industries, the dominant industries were information technology (127 projects), banking (87 projects), insurance (58 projects), health care (65 projects) and manufacturing (66 projects).

4.4 Factors Affecting Technical Efficiency

Project Organization Type: The measure for project organization type is based on the classification scheme described earlier and depicted in Figure 1. Respondents were asked to select one among the five project organization types: Collocated Insourcing, Distributed Insourcing, Outsourcing, Offshoring, and Offshore-Outsourcing. To ensure that the respondents understood the meaning of each project organization type and answered appropriately, a brief definition was provided for each project organization type in the survey. Four categorical variables (DI = 1 for Distributed Insourcing project organization, and 0 otherwise; OUT = 1 for Outsourcing project organization, and 0 otherwise; OFF = 1 for Offshoring project organization, and 0 otherwise; OFFOUT = 1 for Offshore-Outsourcing project organization, and 0 otherwise) representing the five project organization types, with Collocated Insourcing project organization as the base category, were included in the technical efficiency function.

Risk Management Planning: Risk management planning (Cronbach's $\alpha = 0.74$) measures the extent to which potential risks to the project are identified at the beginning of the project, factored into requirements estimate and managed throughout the course of the project. The responses across each item were recorded on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Agile Management: Agile management (Cronbach's $\alpha = 0.72$) measures the extent to which project practices focused on improving project management agility are pursued in a project. Some key practices of this approach include: carrying out multiple iterations of the project prototype in short cycles, concurrent development and testing of project tasks, assignment of project tasks to team members in pairs and encouraging team members to assume collective ownership of the project. The responses across each item were recorded on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Employee Turnover: Employee turnover (Cronbach's $\alpha = 0.74$) in a project team is measured along two key dimensions: (i) whether transition of members within the project team is carried out satisfactorily and (ii) whether team members stayed on the project for a satisfactory duration of time. A total of three items are used to record the scores on these dimensions on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Face-to-Face Interaction: This variable captures the extent to which a project client/client firm and the project team have face-to-face interactions during project execution. Three questionnaire items (Cronbach's $\alpha = 0.80$) are used to measure face-to-face interaction on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

5. Results

The SFA is conducted in two steps. In the first step, we examine whether the output of a project varies as a function of a systematic technical efficiency component in the stochastic production function, besides the effect of project input variables and purely random shocks. The support for the presence of a technical efficiency component provides a logical basis for carrying out the second step in our analysis wherein we investigate the key structural and project management practices that impact technical efficiency. Each step is discussed in greater detail below.

5.1 Estimation of the Production Function and the Technical Efficiency Function

The stochastic production function takes the log-linear form of the Cobb-Douglas production function with natural log transformations of the output variable, input variables and the control variables included in the production function as shown below.

$$
\begin{aligned}
\mathit{lnProject\ Performance} = {} & \left.\begin{aligned} & \beta_0 + \beta_1 \mathit{lnBudget} + \beta_2 \mathit{lnDuration} + \beta_3 \mathit{TeamSize} + \beta_4 \mathit{PastExperience} \\ & + \beta_6 \mathit{TECHUNC} + \beta_6 \mathit{RUUNC} + \beta_7 \mathit{ARCHUNC} \end{aligned}\right\} \textbf{Input Variables} \\
& \left.\begin{aligned} & + \beta_2 \mathit{lnPmRole} + \beta_4 \mathit{ProjectManager} + \beta_6 \mathit{SeniorManager} \\ & + \beta_6 \mathit{Client} + \beta_8 \mathit{ProjectTeam} + \beta_6 \mathit{Hardware} + \beta_8 \mathit{Software} \\ & + \beta_9 \mathit{InformationTechnology} + \beta_{10} \mathit{Insurance} + \beta_{11} \mathit{Banking} \\ & + \beta_{12} \mathit{Healthcare} + \beta_{13} \mathit{Manufacturing} + \beta_{14} \mathit{NorthAmerica} \end{aligned}\right\} \textbf{Control Variables} \\
& \left. + V_i - U_i \right\} \textbf{Composite Error Term}
\end{aligned}
$$

The technical efficiency component was initially specified as a non-negative truncation of the normal distribution with mean zero and unknown variance, σ_u^2. However, the model likelihood function failed to converge under this specification. Therefore, we proceeded with a more parsimonious assumption wherein the technical efficiency component in the production function is assumed to be independently and identically distributed half-normal random variable with mean zero and unknown variance σ_u^2. Further, due to the presence of missing values across some of the key input variables in the production function, we followed a conservative approach in that we estimated the production function for the sub-sample of projects for which we had complete information across all the variables. This reduced the sample to 745 projects.

Table 2 includes the descriptive statistics for the input variables in the production function. Table 3 presents the parameter estimates and the results of the test for the presence of the technical efficiency component in the stochastic production function. The log-likelihood for the stochastic production function, represented by Model 1 in Table 3, is statistically significant (test-statistic = -80.67, $p < 0.01$) suggesting that the collective effect of the input variables and the control variables have significant explanatory value for the output variable. More importantly, the chi-square likelihood test for the presence of a systematic technical efficiency component in the production function is strongly significant ($\chi 2 = 65.36$, $p < 0.01$), thereby supporting a key assumption in our study that the ability to transform project inputs into project outputs varies systematically across the projects.

------------------ Insert Table 2 about here ------------------

Given that the estimation of technical efficiency is of primary interest to our study, and to most studies pertaining to stochastic frontier estimation, a discussion of the actual estimates and predictive value of the individual input variables is only of tangential value (Greene 2003, Coelli et al. 2005). Therefore, we shift our focus toward examining the managerial factors that impact the technical efficiency of a project. The specification of the technical efficiency function is as follows:

$$\begin{aligned} U_i = \quad & \delta_0 + \delta_1 DI + \delta_2 OUT + \delta_3 OFF + \delta_4 OFFOUT \ + \ \delta_5 ln(Face\text{-}to\text{-}FaceInteraction) \\ & + \delta_6 lnRiskManagement \ + \delta_7 lnAgileManagement + \delta_8 ln(EmployeeTurnover) + W_i, \end{aligned}$$

where U_i lies between 0 and 1, and W_i's are independently distributed and are obtained by the truncation of the normal distribution with mean zero and unknown variance σ_u^2. Table 2 presents the descriptive statistics for the quantitative variables in the technical efficiency function. The technical efficiency function is estimated jointly with the stochastic production function and this analysis is conducted with a sample of 704 projects for which complete information was available across all the variables in the stochastic production function and technical efficiency function. Model 2 in Table 3 presents the parameter estimates from both the production function and technical efficiency function.

------------------ Insert Table 3 about here ------------------

Hypothesis 1 posits that distributed project organizations [Distributed Insourcing (DI), Outsourcing (OUT), Offshoring (OFF), and Offshore-Outsourcing (OFFOUT)] will be associated with lower technical efficiency compared to Collocated Insourcing project organization. As is shown in the estimation results for Model 2 in Table 3, among the four categorical variables (DI, OUT, OFF, and OFFOUT) representing the different types of distributed project organization with Collocated Insourcing as the base category, the coefficient estimate for OUT (δ_2= -0.296, $p < 0.01$), OFF (δ_3= -0.590, $p < 0.01$), and OFFOUT (δ_4= -

0.709, $p < 0.01$) are negative and statistically significant. These results indicate that each of the following project organization types – Outsourcing, Offshoring, and Offshore-Outsourcing – is associated with lower technical efficiency compared to Collocated Insourcing project organization. We did not find any significant differences in technical efficiency estimates for projects between Distributed Insourcing and Collocated Insourcing project organizations. Taken together, the above results lend partial support for Hypothesis 1.

Hypothesis 2, which posits a positive association between face-to-face interaction in a project and its technical efficiency, is supported ($\delta_5 = 0.068$, $p < 0.05$). This result indicates that an increase in face-to-face interaction in a project is associated with statistically significant increase in technical efficiency of a project. Hypothesis 3 posits that the use of risk management practices in a project is positively associated with the technical efficiency of a project. The results of our analysis support Hypothesis 3 ($\delta_6 = 0.188$, $p < 0.01$) indicating that greater is the use of risk management practices in projects, greater is the technical efficiency of the projects. Hypothesis 4, which posits a positive association between the use of agile project management practices in a project and technical efficiency of the project, is supported ($\delta_7 = 0.177$, $p < 0.01$). Finally, Hypothesis 5, which posits a negative association between employee turnover in projects and the technical efficiency of projects, is supported ($\delta_8 = -0.155$, $p < 0.01$).

5.3 Robustness of the Model Estimation Results

We also carried out additional analyses to check the robustness of the model estimation results by varying model specifications and estimation procedures. Each of these analyses is discussed below.

Alternative distributions of the composite error term: The composite error term in the stochastic production function consists of a systematic error or a technical efficiency component which is assumed to be distributed as a non-negative truncation of the normal distribution, and a random error component which is always assumed to be distributed as a two-sided normal distribution. To check whether our results are robust to alternate specifications of the systematic error or the technical efficiency component, we re-estimated the parameters in the technical efficiency function by specifying an exponential and half-normal distribution for the technical efficiency component, respectively. Both the signs and the statistical significance of the parameters in the technical efficiency function were consistent with our original analysis, thereby re-affirming the robustness of our results (see Appendix for details).

Inclusion of more project-specific variables in the technical efficiency function: We added a number of other project specific variables in the technical inefficiency function as control variables, to check whether the results of the analysis to test the hypotheses, discussed earlier, differed significantly. Specifically, we included the following variables: *internal knowledge sharing* and *external knowledge sharing* within and between the project team and the project client; the *shared context*—similarity of information, tools, work processes and work cultures—between the project team and the project client; *project control* and *project autonomy* exercised in a project; and *diversity* within a project team in terms of functional background, years of experience, language and cultural background. We did not see any significant differences in the results from this analysis from our original analysis (see Appendix for details).

6. Discussion

6.1 Variation in Technical Efficiency across Project Organization Types

Results from the study indicate that technical efficiency of a project varies with the choice of the type of the project organization for the project. Consistent with the hypothesis that transaction costs and information processing difficulties are considerably higher in distributed project organizations compared to Collocated Insourcing project organization, the results indicate that Outsourcing, Offshoring, and Offshore-Outsourcing project organizations are associated with significantly lower levels of technical efficiency compared to Collocated Insourcing project organization. Further, since there are no significant differences between technical efficiency of Collocated Insourcing and Distributed Insourcing project organizations, the results also emphasize that mere geographical distance between a project client and the project team in project organizations that are that are located within a single country does not necessarily lead to reduction in technical efficiency .

A review of summary statistics for technical efficiency estimates by the type of project organization in the study sample reveals some interesting trends. As is evident from both Table 3 and Figure 3, the mean technical efficiency decreases across project organization types in the following order (from highest to lowest): Collocated Insourcing > Distributed Insourcing > Outsourcing > Offshoring > Offshore-Outsourcing. It is notable that there is a sharp decrease in the mean technical efficiency estimates for Offshoring and Offshore-Outsourcing project organization, compared to that for Outsourcing project organization, suggesting that the distribution of projects across country boundaries poses substantial coordination and resource utilization problems compared to project distributed across firm boundaries.

It should be noted that the above results do not imply that distributed project organizations, particularly Offshoring and Offshore-Outsourcing project organizations, cannot achieve levels of technical efficiency that is comparable with Insourcing project organization. A comparison of the mean technical efficiency estimates for the projects whose technical efficiency is in the top 10% (see Table 4) within a type of project organization reveals that the differences in the means are marginal. This finding implies that that each of the five types of project organization represent viable alternatives for managers to achieve a high level of technical efficiency. In contrast, a comparison of the mean technical efficiency estimates for projects whose technical efficiency is in the bottom 10% (see Table 3) within type of project organization indicates substantial differences between Offshoring and Offshore-Outsourcing project organizations, and Collocated Insourcing project organization. This implies that when things go wrong, they are likely to go really wrong in Offshoring and Offshore-Outsourcing project organizations. A comparison of the standard deviation estimates across the different types of project organization, shown in Table 4, supports the above inferences by illustrating increased variation in technical efficiency estimates for Offshoring and Offshore-Outsourcing project organizations.[7]

------------------ Insert Table 4 and Figure 3 about here ------------------

6.2 Impact of Project Management Factors on Technical Efficiency

We infer from the empirical analysis results that face-to-face interaction between a project team and the project client can be helpful in enhancing the technical efficiency of a project. While this result is somewhat intuitive, it emphasizes the point that frequent face-to-face interaction between a project team and the project client resolve potential misunderstandings and set the ground for a smoother day-to-day execution of project activities. A richer communication medium, as in the case of face-to-face interaction, provides a project team with a deeper understanding of the project client's requirements and can lead to better mobilization, allocation and utilization of resources in key areas of the project. In contrast, minimal or not face-to-face interactions can leave project teams in distributed settings highly vulnerable to process losses and performance problems (Gibson & Cohen 2003, Lipnack & Stamps 2000). The following

[7] We caution that the above findings based on mean technical efficiency estimates should not be extrapolated to imply any trends in absolute project performance outcomes across the different types of project organization. This is due to the fact that there is no sound theoretical basis for establishing correspondence between the estimates of technical efficiency and project performance. Technical efficiency of a project reflects the ability of a project to convert project inputs into project outputs (meet project performance goals). Thus, a project with high technical efficiency could have low project performance and vice versa.

anecdotal example of an information technology project is illustrative of the potential inefficiencies that can arise from lack of face-to-face interactions between a project team and the project client:

> "Vendor project team members, working under the scope and approach defined in the contractual statement of work, wanted to complete the enterprise-wide requirements before going into the details and measured the team's success on how effectively (high speed, high quality, low cost) it did so. However, to reduce the time to market, the client's CIO wanted to proceed on the basis of priority, first completing detailed requirements for one specific business area. A meeting between client and vendor decision makers failed to find a resolution, because the remotely located vendor team members with RE [requirements engineering] process knowledge couldn't participate. This created a conflict, because as the vendor team introduced more resources to accelerate the pace of collecting the enterprise-wide business requirements, the CIO maintained focus to prioritize one specific business area. Because the two organizations' stakeholders didn't explicitly discuss the business goals and their rationale, neither side appreciated the RE exercise's outcome." (Bhat et al. 2006, p. 40).

Project management practices geared toward identifying and managing project risks and increasing the agility of project execution can be useful in improving the technical efficiency of a project. Specifically, the results presented in Table 3 indicate the following: 1-unit increase in risk management planning increases the technical efficiency of a project by 0.188 unit, whereas a 1-unit increase in agile management practices increases the technical efficiency of the project by 0.177 unit. The result with respect to agile management practices highlights the benefits of pursuing an iterative and incremental process to project execution with collective involvement of both the members of a project team and the project client, over traditional sequential/waterfall approach to project execution. Similarly, a heightened awareness to project risks and pursuing project management practices that identify and plan for anticipated risks can go a long way toward improving the technical efficiency of a project.

Finally, with respect to the relationship between employee turnover and technical efficiency in a project, our result confirms that increasing employee turnover is associated with decreasing technical efficiency. Empirically, this result fills an important void in the literature on employee turnover and project management. While there are anecdotes extolling efforts to reduce employee turnover as being related to the improvement of efficiency in project execution, there is little empirical support for such relationship documented in the literature. Further, the magnitude and the statistical significance of this relationship stress the notion that employee turnover could indeed be a barrier to efficient project execution and, hence, managers should strongly focus on minimizing not only the outflow of important human resources from a project, but also avoid frequent transitions across projects.

To examine whether the impact of project management factors on technical efficiency varies across the different types of project organizations (i.e., greater or lower impact on technical efficiency in distributed project organization compared to Collocated Insourcing project organization), we re-specified the technical efficiency function to test the moderating (i.e., interaction) effect of the type of project organization on the relationship between project management factors and technical efficiency. Our analysis did not reveal the presence of any statistically significant interaction effects, thereby indicating that each of these sets of project management factors were equally beneficial across the different types of project organizations. Nevertheless, given the lower technical efficiency of Offshoring and Offshore-Outsourcing project organizations, it is imperative for managers in such project organizations to emphasize risk management, agile project management and timely face-to-face interaction while making concerted effort to reduce employee turnover.

7. Conclusion

This study was motivated by the growing realization that as projects, such as new product development and information technology projects, are becoming more and more distributed across firm and geographical boundaries, concerns about the efficiency of execution of such projects are growing. In this study, we investigated how the choice of the type of project organization was related to project efficiency, and identified project management factors that are enablers and barriers to the efficiency of project execution. Using a classification scheme based on the extent to which project organizations span firm and geographical boundaries, we identified five distinct types of project organization, namely, Collocated Insourcing, Distributed Insourcing, Outsourcing, Offshoring, and Offshore-Outsourcing. We presented an econometric approach to measure project efficiency. Using stochastic frontier analysis, the specific form of project efficiency we measured was technical efficiency, defined as the ability of a project (or any productive entity) to obtain maximal attainable outputs from a given set of inputs. The empirical analysis was based on primary data collected from more than 700 projects, a mix of product development and information technology projects. Projects from 26 industries and across 65 countries are represented in the study sample.

The key contribution of this study is in shedding light into the execution phase of projects and providing insights into how the project execution phase can be managed so as to improve the efficiency of project execution. While there are anecdotes and empirical studies documenting performance outcomes of projects in outsourcing and offshoring contexts, relatively little is documented by way of either measurement of project efficiency or factors that are either enablers or barriers to project efficiency. First and foremost, we infer from this study's results that the choice of the type of project organization is associated with project efficiency. Specifically, distributed project organizations, particularly Offshoring and Offshore-Outsourcing project organizations, exhibit significantly lower technical efficiency compared to Collocated Insourcing project organization. We also identified project management practices that were significantly associated with project efficiency. Specifically, risk management planning, agile management, and face-to-face interaction are positively associated with the technical efficiency of projects; and employee turnover is negatively associated with technical efficiency of a project.

As with any study, this study has limitations and appropriate caution should be exercised in interpreting the study results. *First*, the use of a single informant for collecting information on a project is a limitation. While multiple informants would have increased the reliability of the study's findings, this is normally possible when data collection is carried out within a single firm. In this study, since we conceptualized project organization into five different types, the empirical testing of the study's hypotheses warranted a data collection approach that would allow for collection of a large sample of data from projects across the five different types of project organization, all of which is seldom found within a single firm. Our purpose in reaching out to professional management associations (PMI –ISSIG and PMI-NPDSIG) for data collection was to ensure that we have a sampling frame that included project management professionals from different firms in different industries and from different countries. This, however, limited our ability to collect data on each of the projects in the study sample using multiple informants. Further, the respondents to our web-based survey questionnaire had various kinds of affiliations to a project (i.e., project client/client firm or project team/vendor firm or external consultant). While we controlled for heterogeneity in respondent affiliations in our empirical analysis, future research studies could certainly improve upon our study by collecting survey data on each project from multiple respondents with different affiliations to the same project.

The *second* limitation of our study relates to a larger representation of information technology projects in our study sample compared to physical product development projects. Future studies should strive for a more balanced sample with equitable representation of physical product development and information technology projects to avoid the potential for bias due to project type in the study results. The *third* limitation of our study relates to the presence of heterogeneity effects of different firms, industries and geographical regions in our data. While we have controlled for industry and geographical-region effects, the absence of firm level controls is a limitation.

Notwithstanding the above limitations, this study lays the groundwork for systematically and rigorously measuring the efficiency of project execution and identifying its antecedents for projects distributed across firm and geographical boundaries. Since more and more product development and information technology projects, the empirical setting of this study, are being distributed across firm and geographical boundaries, the questions addressed in this study are both contemporary and consequential and, hence, should motivate other researchers to pursue this line of inquiry.

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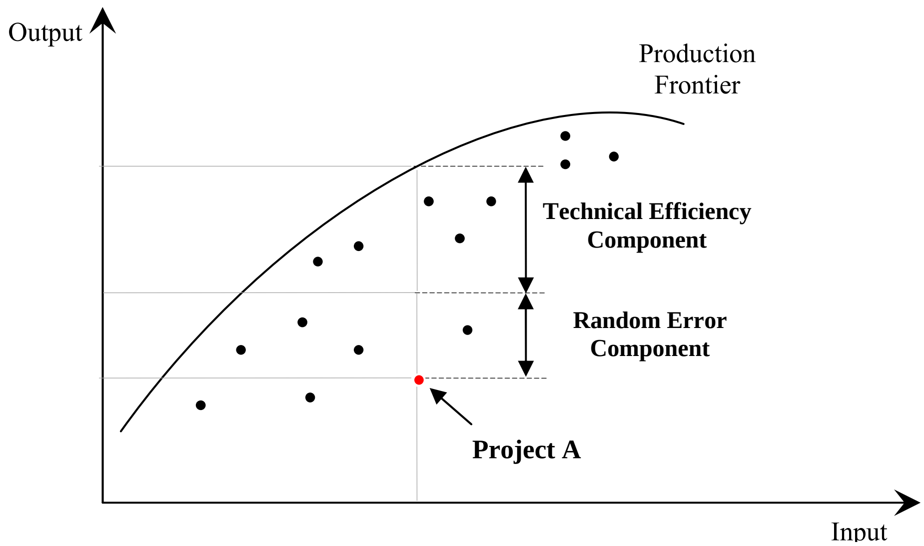

Figure 1: Decomposition of the error term in the stochastic frontier analysis (SFA) models

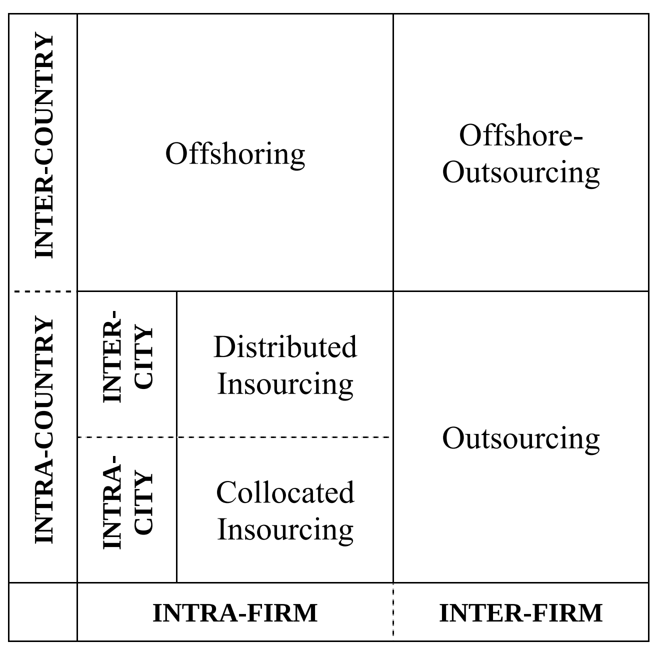

Figure 2: Project Organization Types

Table 1: Measurement Items in the Survey Questionnaire

Select one of the choices which best reflects the organization of the project.
Collocated Insourcing **[CI]**: Firm assigns project tasks to a collocated inhouse team
Distributed Insourcing **[DI]**: Firm assigns project tasks to its division/unit at a different city in the same country
Outsourcing **[OUT]:** User firm/Client firm contracts project tasks to a Vendor Firm in the same country
Offshoring **[OFF]:** User firm/Client firm contracts project tasks to its division/unit in a different country
Offshore-Outsourcing **[OFFOUT]:** User firm/Client firm contracts project tasks to a Vendor Firm in a different country

Please rate the success of this project relative to its goals [ProjectPerformance] (α = 0.90**)**
(1= Significantly Worse; 2 = Worse; 3 =Somewhat Worse; 4 = About Same; 5 = Somewhat Better; 6 = Better; 7 = Significantly Better)

Adherence to schedule
Adherence to budget
Adherence to quality
Technical performance
Overall satisfaction

To what extent do you agree or disagree with the following statements about the project
Strongly Disagree; 2 = Somewhat Disagree; 3 = Neutral; 4 = Somewhat Agree; 5 = Strongly Agree)

Technology Uncertainty* **[TECHUNC]** (*α* = 0.76**)**
Technical requirements of the project were well understood by the project team
Existing technical knowledge of the project team was used during the project
An understandable sequence of steps was used by the project team during the project
The technical objectives of the project were well defined for the project team

Architectural Uncertainty*[ARCHUNC] (*α* = 0.76**)**
The project could be easily divided into task modules
Interdependencies across task modules were clearly defined
It was easy to define the interdependence among task modules in the project

Requirements Uncertainty [RUUNC](*α* = 0.85**)**
Client firm requirements fluctuated significantly at the start of the project
Client firm requirements fluctuated significantly midway into the project
Client firm requirements changed continuously throughout the project
Client firm requirements remained stable throughout the project**

Past Experience [PastExperience] (α = 0.75**)**
Team members had worked on similar projects in the past
The project manager had past experience of managing projects of similar scope/size
Team members had dealt with user firm requirements of similar type in past projects
The project manager had past experience or working in a similar project organization

Risk Management [RiskManagement] (α = 0.74**)**
Contingency plans were prepared to minimize project risks
The project team managed potential risks throughout the projects
Requirement estimates for the project accounted for potential risks
Potential risks were identified by the project team at the start of the project

Agile Management [AgileManagement] (α = 0.72**)**
There were several iterations of the prototype during the project
Small releases of the prototype were carried out frequently
Test plans and development work were carried out concurrently
Component designs were reviewed for efficiencies when adding more functionality
Team members pursued the practice of collective ownership of the project
Team members pursued the practice of collective ownership of the project

Facet-to-Face Interaction [FacetoFace] (α = 0.74**)**
Initially, face-to-face interaction was used to gather project requirements
Atleast one or more team members were in constant face-to-face contact with the project client
Key team members and the members of the project client met face-to-face initially to discuss their expectations

Employee Turnover [EmployeeTurnover] (α = 0.80**)**
Critical team member(s) left the project team midway into the project
The duration of stay of members in the project team was satisfactory
The management of transition of members within the project team was unsatisfactory

* Items representing these constructs were reverse coded during analysis for ease of interpretation

** represents an item reverse coded during analysis

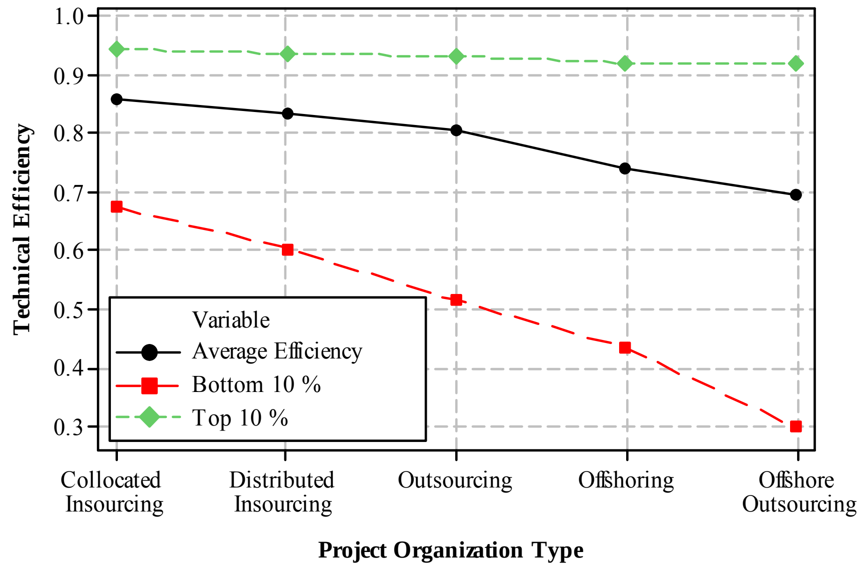

Figure 3: Variation in technical efficiency levels across project organization types

Table 2: Descriptive Statistics: Input and Technical Efficiency Variables

Input Variables	**Mean**	**Std. Dev.**
ProjectPerformance	4.35	1.27
Budget	5.32	1.71
Duration	14.37	12.27
TeamSize	27.48	42.78
PastExperience	3.75	0.87
TECHUNC	2.17	0.81
RUUNC	2.99	1.07
ARCHUNC	2.41	.85
Technical Efficiency Variables	**Mean**	**Std. Dev.**
FacetoFace	2.28	1.08
RiskManagement	3.43	0.99
AgileManagement	3.13	0.78
EmployeeTurnover	3.97	1.08

TECHUNC: Technological Uncertainty, RUUNC: Requirements Uncertainty, ARCHUNC: Architectural Uncertainty

Table 3: Parameter Estimates of Stochastic Frontier Models

	OutputVariable: lnProjectPerformance		
		Model 1	**Model 2**
Input Variables	lnBudget	.017	.019
	lnDuration	-.013	-.011
	lnTeamSize	-.007	.003
	lnPastExperience	.049	-.002
	lnTECHUNC	-.327**	-.232**
	lnRUUNC	.008	-.009
	lnARCHUNC	.069*	.051†
Technical Efficiency Variables	Distributed Insourcing **[DI]**		-.212
	Outsourcing **[OUT]**		-.296*
	Offshoring **[OFF]**		-.590**
	Offshore Outsourcing **[OFFOUT]**		-.709**
	FacetoFace		.068**
	RiskManagement		.188**
	AgileManagement		.177**
	EmployeeTurnover		-.155**
Control Variables	lnPmRole	-.028†	-.024
	ProjectManager	.087**	.076**
	SeniorManager	.057	.047
	Client	-.044	-.047
	ProjectTeam	.012	-.022
	Hardware	-.081**	-.049*
	Software	-.079**	-.071**
	InformationTechnology	-.021	-.038
	Insurance	.017	.028
	Banking	.009	.016
	Healthcare	-.033	-.034
	Manufacturing	-.035	-.033
	NorthAmerica	-.010	-.015
	Variance Parameters		
	σ_v	.145	.164
	σ_u	.396	.379
	Test for technical efficiency Ho : No technical efficiency component	$\chi^2 = 65.36$**	-
	Log-likelihood Function	-80.667	8.453
	Sample size (n)	745	704

†p< 0.1, * p< 0.05, ** p < 0.01

TECHUNC: Technological Uncertainty, RUUNC: Requirements Uncertainty, ARCHUNC: Architectural Uncertainty

Table 4: Technical Efficiency Levels across Project Organization Types

Project Organization Type	N	Average Efficiency	Std. Dev.	*t*-test for mean differences	Average Lowest Efficiencies (Bottom 10%)	Average Highest Efficiency (Top 10%)
Collocated Insourcing **[CI]**	261	0.857	0.084	-	0.674	0.944
Distributed Insourcing **[DI]**	117	0.832	0.099	1.92†	0.604	0.936
Outsourcing **[OUT]**	152	0.807	0.130	4.36**	0.515	0.932
Offshoring **[OFF]**	54	0.739	0.150	5.93**	0.435	0.920
Offshore-Outsourcing **[OFFOUT]**	120	0.697	0.184	9.07**	0.299	0.921

† $p < 0.1$, * $p < 0.05$,** $p < 0.01$

Appendix: Robustness of the Model Estimation Results

Alternative distributions of the composite error term: The composite error term in the stochastic production function consists of a systematic error or a technical efficiency component which is assumed to be distributed as a non-negative truncation of the normal distribution, and a random error component which is always assumed to be distributed as a two-sided normal distribution. To check whether our results are robust to alternate specifications of the systematic error or the technical efficiency component, we re-estimated the parameters in the technical efficiency function by specifying an exponential and half-normal distribution for the technical efficiency component, respectively.

As Table A1 and A2 below indicate, the signs and the statistical significance of each of the parameter estimates in the technical efficiency function were consistent with our original analysis. Collectively these findings indicate the robustness of our results to alternate specifications of the composite error term.

Table A1: Alternative Specification of Technical Efficiency Component: Exponential Distribution

```
Stoc. frontier normal/exponential model          Number of obs   =        704
                                                 Wald chi2(20)   =     115.01
Log likelihood =  6.1025715                      Prob > chi2     =     0.0000
```

	Coef.	Std.Err	z	P>|z|	[95% Conf. Interval	
Distributed Insourcing **[DI]**	0.492	0.416	1.180	0.237	-0.323	1.306
Outsourcing **[OUT]**	0.907	0.368	2.460	0.014	0.185	1.628
Offshoring **[OFF]**	1.887	0.460	4.110	0.000	0.986	2.787
Offshore Outsourcing **[OFFOUT]**	2.240	0.383	5.850	0.000	1.489	2.991
RiskManagement	-0.528	0.141	-3.740	0.000	-0.804	-0.251
AgileManagement	-0.470	0.171	-2.750	0.006	-0.805	-0.135
FacetoFace	-0.252	0.109	-2.320	0.021	-0.465	-0.039
EmployeeTurnover	0.474	0.111	4.270	0.000	0.256	0.692

Table A2: Alternative Specification of Technical Efficiency Component: Half-Normal Distribution

```
Stoc. frontier normal/half-normal model          Number of obs   =        704
                                                 Wald chi2(20)   =     107.43
Log likelihood =  8.0450198                      Prob > chi2     =     0.0000
```

	Coef.	Std.Err	z	P>|z|	[95% Conf.Interval	
Distributed Insourcing **[DI]**	0.315	0.268	1.180	0.240	-0.210	0.840
Outsourcing **[OUT]**	0.665	0.248	2.680	0.007	0.178	1.151
Offshoring **[OFF]**	1.369	0.325	4.210	0.000	0.732	2.007
Offshore Outsourcing **[OFFOUT]**	1.698	0.278	6.110	0.000	1.153	2.243
RiskManagement	-0.374	0.096	-3.910	0.000	-0.562	-0.187
AgileManagement	-0.316	0.113	-2.800	0.005	-0.538	-0.095
FacetoFace	-0.204	0.074	-2.760	0.006	-0.349	-0.059
EmployeeTurnover	0.321	0.077	4.160	0.000	0.170	0.472

Inclusion of more project-specific variables in the technical efficiency function: We added a number of other project specific variables in the technical inefficiency function as control variables, to check whether the results of the analysis to test the hypotheses, discussed earlier, differed significantly. Specifically, we included the following variables: *internal knowledge sharing (IntKnowledge)* and *external knowledge sharing (ExtKnowledge)* within and between the project team and the project client; the *shared context (SharedContext)*—similarity of information, tools, work processes and work cultures—between the project team and the project client; *project control (ProjectControl)* and *project autonomy* (*ProjectAutonomy*) exercised in a project; and *diversity* within a project team in terms of functional background, years of experience, language and cultural background. We did not see any significant differences in the results from this analysis, as shown below in Table A3, from our original analysis.

Table A3: Analysis using Additional Project Specific Variables in the Technical Efficiency Function

```
Stoc. frontier normal/truncated-normal model      Number of obs   =        685
                                                  Wald chi2(20)   =      82.46
Log likelihood =  17.867445                       Prob > chi2     =     0.0000
```

	Coef.	Std.Err	z	P>|z|	[95% Conf.	Interval
Distributed Insourcing **[DI]**	0.123	0.106	1.160	0.246	-0.085	0.330
Outsourcing **[OUT]**	0.235	0.109	2.170	0.030	0.023	0.448
Offshoring **[OFF]**	0.433	0.142	3.050	0.002	0.155	0.710
Offshore Outsourcing **[OFFOUT]**	0.504	0.131	3.860	0.000	0.248	0.761
RiskManagement	-0.162	0.044	-3.650	0.000	-0.249	-0.075
AgileManagement	-0.158	0.052	-3.040	0.002	-0.261	-0.056
FacetoFace	-0.047	0.027	-1.740	0.082	-0.101	0.006
EmployeeTurnover	0.105	0.032	3.300	0.001	0.043	0.168
IntKnowledge	0.009	0.051	0.180	0.861	-0.091	0.109
ExtKnowledge	0.014	0.043	0.310	0.754	-0.071	0.098
SharedContext	-0.122	0.038	-3.220	0.001	-0.196	-0.048
ProjectControl	0.022	0.043	0.510	0.611	-0.062	0.105
ProjectAutonomy	0.058	0.039	1.490	0.136	-0.018	0.135
Diversity	0.062	0.035	1.760	0.079	-0.007	0.131