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

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Efficiency in project execution is a central concern in project management. Concerns about the efficiency of project execution, such as the execution of information technology and product development projects, have been exacerbated as projects are 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 *structural* and *infrastructural* factors to explain the variation in technical efficiency across projects is specified and estimated. The structural 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 infrastructural 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 organization types, 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 the 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

> "The difficult economic conditions will push companies further than before to consider what stays in house and what gets done by others. Additionally, demands by the business for further cost reduction will need to be addressed [by suppliers and offshore vendor firms] in an environment where many companies have already leveraged labor arbitrage to source the low hanging fruit." (Eugene Kublanov, CEO, NeoIT on www.cio.com[1])

As the current global economic recession continues, increasing competitive pressures are forcing many firms to reconfigure their organizational arrangements for executing projects, with project organizations transcending boundaries of firms and countries. Concurrently, suppliers and offshore vendor firms are facing an increasing demand to provide their services and execute projects at significantly reduced profit margins. As a result, identifying the sources of project efficiencies and managing them effectively has become not only critical for the successful execution of distributed projects, but also for the survival of existing firm-supplier relationships (Lewin et al. 2009).

[1]http://www.cio.com/article/471713/Offshoring_and_Outsourcing_in_What_Does_the_Future_Hold_for_the_IT_Services_Industry

A recent survey of firms engaged in offshoring reports that the majority indicated improvements in project efficiencies as their primary motivation for offshoring their business processes.[2] However, successes in executing projects such that gains in project efficiencies are realized have not been universal (Hinds and Mortensen 2005). Recent industry studies—namely, A.T. Kearney's 2007 Offshoring Success Study[3] and Deloitte's 2007 Financial Services Offshoring Study[4]—on the outsourcing and offshoring of organizational work indicate a significant gap between managerial expectations and actual outcomes. For example, the A.T. Kearney 2007 Offshoring Success Study reports that 60% of the surveyed companies seemed to fall short of their operational performance expectations. These studies not only highlight the inefficiencies associated with distributed project organizations, they also challenge the conventional wisdom of the practitioner literature and media reports which suggest that efficiency gains are synonymous with distributed project organizations. Identifying, *ex ante*, the enablers and barriers to attaining higher project efficiency is becoming imperative for the successful execution of distributed projects. This study is motivated by the following questions:

- *How does the efficiency of distributed project organizations compare with those that are not distributed?*
- *What are the key project execution factors 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 these questions. Frequently, decisions related to outsourcing or offshoring project work are made at the top management level with expectations of certain performance outcomes (Williamson 1975, Montverde and Teece 1982, Holmstrom and Milgrom 1994). Operational level issues and risk factors regarding the organization and 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 2001). Thus, while a few projects may be efficient in making use of their input resources and meeting their output goals, the significant majority of projects are typically inefficient in realizing their output goals.

[2] Duke University/Pricewaterhouse Coopers Offshoring Research Network Focus 2008 Survey

[3] A.T. Kearney. 2007. Execution is Everything: The Keys to Offshoring Success. http://www.atkearney.com/main.taf?p=5,3,1,157

[4] http://www.deloitte.com/dtt/research/0,1015,cid%253D161519,00.html

Despite the relevance of these issues to research and practice, academic literature at the intersection of sourcing decisions and project efficiency is practically non-existent. More broadly, research on project efficiency has been limited, its growth stunted by the methodological challenges and simplifying assumptions in analytical and empirical studies. 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 (Nelson 1982). Thus, the 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 implicit assumption that projects are operating on an efficiency frontier (i.e., projects are fully efficient in their use of input resources). The limited number of empirical studies that have studied project efficiency conceptualize and specify this term as a dependent variable (in econometric models) that captures the performance of a project on various output dimensions such as cost, schedule, quality, etc. (e.g., Faraj and Sproull 2000, Sobrero and Roberts 2001, Ancona and Caldwell 1992).[5] By confounding project output dimensions with project efficiency, these studies assume that differences in project efficiency are *exclusively* due to differences in levels of project inputs or purely random shocks. Such assumptions are rarely reflective of most productive entities in the real world (Coelli et al. 2005). As Kamien and Schwartz (1975) aptly observe, while input resources are critical to achieving the necessary outputs, very often the transformation of inputs to outputs is governed by other systematic factors.

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 the efficiency of productive entities. The stochastic frontier analysis (SFA) approach, therefore, serves as this study's foundation to specify and estimate the sources of inter-project differences in efficiency. Specifically, by conceptualizing project execution as an economic production process that transforms a set of inputs into valuable outputs (Banker et al. 1991, Verma and Sinha 2002), this study specifies and estimates project efficiency in the form of technical efficiency,[6] defined as the

[5] Notable exceptions to this generalization include studies by Banker et al. (1991), Verma and Sinha (2002), Farris et al. (2006) and Swink et al. (2006) that use Data Envelopment Analysis (DEA) methodology to obtain the relative efficiency of projects with respect to a performance frontier derived from a small sample of highly efficient peers.

[6] 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 and determines whether production inputs are used in proportions that ensure maximum output at

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 *structural* and *infrastructural* project factors (Hayes and Wheelwright 1984) to explain variations in technical efficiency.

Structural factors are long-range and have strategic implications. Decisions based on structural factors are typically carried out before the onset of project execution (i.e., during the project planning stage) and are not easily reversible once they have been made. In this study, we identify the choice of the type of project organization[7] as a key structural factor. Project organization plays a central role in influencing the information processing capabilities of a project. As project organizations become increasingly distributed (a project is simultaneously distributed across multiple boundaries, such as firm boundaries and geographical boundaries), information processing challenges during project execution increase. Sustaining a 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. So, we first examine whether systematic differences in technical efficiency across projects can be explained by their choice of project organization type (namely, *Collocated Insourcing*, *Distributed Insourcing*, *Outsourcing*, *Offshoring* and *Offshore-Outsourcing)*.

Next, we investigate the effects of infrastructural factors on the technical efficiency of a project. Infrastructural factors involve operational factors or project management practices that are tactical in nature and are likely to influence the execution phase of a project. Specifically, this study examines the effect of infrastructural factors including *face-to-face interaction* (between a project client and a project team), *risk management planning*, *agile management practices*, and *employee turnover* on the technical efficiency of a project.

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

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minimum input prices. Since input prices are generally difficult to quantify and are not easily obtainable (Greene 1997), we focus primarily on examining the technical efficiency of projects in this study.

[7]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.

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 the 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.

This study makes important conceptual and methodological contributions to the literature on project evaluation. While the extant literature has been, at best, diagnostic, focusing mainly on benchmarking projects with respect to the efficient frontier, our study extends the literature by developing a conceptual framework that identifies key structural and infrastructural factors impacting the technical efficiency of a project. In testing the hypothesis derived from the conceptual framework, the econometric approach of SFA is used. To the best of our knowledge, this study marks the first attempt in the project evaluation literature to use SFA to obtain individual estimates of technical efficiency of a project—for performing a comparative evaluation of technical efficiency across the various types of project organizations—and investigate project management practices that affect the technical efficiency of a project.

The remainder of the paper is organized as follows. Section 2 discusses the methodology of SFA 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 the 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 concludes by outlining the study's contributions, limitations, and directions for future research.

2. Stochastic Frontier Analysis (SFA)

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

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

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. Any deviation from the production frontier is assumed to be a function of completely random producer-specific shocks. 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 production frontier and evaluate the projects relative to the production 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 production frontier is composed of a random error component and a systematic technical efficiency component.

The stochastic production function with a random error component and a technical efficiency 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 the maximum feasible output. The random error component, exp (V_i) that describes random shocks affecting the transformation process which converts a project's inputs to output. These random shocks may occur on account of macroeconomic cycles or plain luck. 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 $0 \leq TE_i \leq 1$. Now, if we also assume that $f(X_{i;}\ \beta)$ takes the log-linear Cobb-Douglas form, the stochastic production function can be written as:

$$\ln Y_i = \beta + \sum \beta_n \ln X_{ni} + V_i - U_i \qquad \text{---------------- (1)}$$

where V_i is the "noise" component, which we will almost always consider a two-sided normally distributed variable with mean zero and unknown variance σ_v^2, and U_i is the non-negative technical efficiency component. A common assumption in the stochastic frontier literature is that U_i is independently and identically distributed as a non-negative truncated-normal distribution with an unknown mean μ and variance σ_u^2, i.e., $U_i \sim$ iid $N^+(\mu, \sigma_u^2)$. A more parsimonious half-normal distribution (i.e., $U_i \sim$ iid $N^+(0, \sigma_u^2)$) has often been substituted in favor of the less-restrictive assumption of a non-negative truncated normal distribution to circumvent issues that arise during model estimation (Greene 1997). If heterogeneity across projects in the study sample with respect to input resource utilization exists, most projects would be technically inefficient and would lie below the estimated production frontier[8]. Thus, the composed error component ($V_i - U_i$) would be negatively skewed and a chi-square test for negative skewness of residuals from the production function would support the presence of a technical efficiency component.

Given the primary focus of this study is to identify factors affecting the technical efficiency of a project, we use Battese and Coelli's (1995) method for parameterizing the technical efficiency component, U_i, as a function of additional, project-specific variables. The technical efficiency function is written as:

$$U_i = Z_i\delta + W_i \qquad \text{---------------- (2)}$$

where Z_i is a vector of explanatory variables, like 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 from a non-negative truncated-normal distribution with unknown mean μ and unknown variance σ_u^2. Following this specification, the production function and technical efficiency function are jointly estimated by maximizing the sample likelihood function given by:

$$L = \prod_{i=1}^{n} \frac{1}{\sqrt{\sigma_u^2 + \sigma_v^2}} \times \left[1 - \Phi\left(\frac{\sigma_u[Y_i - f(X_i, \boldsymbol{\beta})]}{\sigma_v\sqrt{\sigma_u^2 + \sigma_v^2}} - \frac{\sigma_v \mu}{\sigma_u\sqrt{\sigma_u^2 + \sigma_v^2}}\right)\right] \times \phi\left(\frac{Y_i - f(X_i, \boldsymbol{\beta}) + \mu}{\sqrt{\sigma_u^2 + \sigma_v^2}}\right) \times \left[1 - \Phi\left(-\frac{\mu}{\sigma_v}\right)\right]^{-1}$$

---------------- (3)

where $\Phi(.)$ and $\phi(.)$ denote the standard normal distribution and density functions, respectively. Consistent and efficient estimates of the model parameters in (1) and (2) are obtained by maximum likelihood estimation of (3).

[8] Although the production function in SFA models is reformulated from a "function" (as in OLS) to a "frontier" (i.e., designed to bound data from above, rather than passing through it), there is a possibility that a project will end up above the deterministic kernel of estimated production frontier due to an operating environment that is unusually favorable. Kumbhakar and Lovell (2000, p. 3-4) point out that such operating environments are less likely because if environmental effects are random as is typically assumed, then an unfavorable operating environment is just as likely to occur as is a favorable operating environment, and this causes a project to end up beneath an estimated production frontier.

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: one dimension representing the geographical distribution of project organizations within and between national boundaries, and another 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.

- **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 their 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 they 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 the 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 generally mesh the activities of the team. Often, project team members may need to communicate and convince project client members of their views on 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 to swiftly resolve the sorts of contentious 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—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, inhibit real time information exchange and contribute to difficulties in information processing. Further, since both the project client and the project team 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, these arguments suggest that the increased inefficiency of information processing in distributed project organizations compared to Collocated Insourcing project organization renders them comparatively 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 in teams is typically achieved on a daily basis through technology use, such a medium is rarely efficient when it comes to the 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 more biased in distributed teams (Hightower and Sayeed 1995, 1996, Hollingshead 1996), but it was also less efficient and proceeded at a slower rate (Lebie et al. 1996, Straus 1997, Straus and McGrath 1994). Frequent and timely face-to-face communication between a project team and the project client can go a long way toward addressing such problems, helping both constituents 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 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 project client and project team employees and which can hamper the progress of a project. For these reasons, we propose the second 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 is being increasingly stressed as a way of achieving fast responsiveness to changing project requirements. Agile project management is a highly iterative and incremental process, wherein a project team and the project client actively work together to understand project requirements, identify what project activities needs to be executed, and prioritize functionality (Chin 2004). Again, this differs from the traditional approach to project management in that the amount of time 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 leads 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 these 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 including unrealistic schedules and budgets, continuous requirement changes, lack of relevant knowledge, and employee turnover. Risk management planning, then, is defined as 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 et al. 1993). For example, Barki et al. 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 a 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, emphasizing potential causes of failures, helping to link potential threats to possible actions, and facilitating a shared perception of the project among its participants (Lyytinen et al. 1998). Risk management planning helps minimize conflict among project team members, reduces the amount of rework in a project during the later stages, and leads to a more efficient use of project resources (Loch et al. 2006). Beyond 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), 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

Employee turnover in organizations has been the subject of considerable research (Ton and Huckman 2008, Glebbeek and Bax 2004). Although most studies have recognized employee turnover as 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 accumulated employee experience, while others have suggested that firms may actually benefit from the innovative thinking and 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 certainly 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 of their resignation or receives notice for termination of employment, he or she is likely to lose focus and become less productive. Further, during the transition period, 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 will increase to offset the vacant position. Second, the process of finding a suitable replacement for those leaving a project midway is time consuming. Even if a suitable replacement employee is found quickly, there is an initial "set-up cost" involved—that is, the replacement team member will need time to get familiar 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). All together, these 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 pre-tested with three university researchers and two practitioners to assess content validity and the 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 the Project Management Institute's (PMI) local chapter in Pune, India.[9] This round of pre-testing allowed us to test the web-based version of our survey in conditions similar to those in an actual survey implementation. Overall, the two rounds of pre-testing helped us gauge initial reactions to the survey and identify questions that were confusing or 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).[10] Two follow-up reminders were sent approximately one week and four weeks apart from the date of the first mailing and led to a total of 675 usable responses, 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 is lower than the typical rates for survey research for several reasons. First, the sampling frame of the PMI-ISSIG consists of many project management professionals who have little or no experience working on any form of distributed project organization, and they are less likely to respond to our survey. Tanriverdi et al. (2007) point out 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

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[9] Both PMHUB and PMI (www.pmi.org) are well recognized professional associations within the project management community that serve as platforms for project management professionals to share ideas and experiences, access industry information, attend seminars and workshops, increase professional exposure through networking, and gain leadership experience.

[10] The specific interest groups (SIGs) are PMI subgroups that promote member exchange of knowledge concerning the application of project management practices, issues, and challenges in specific contexts. The PMI-ISSIG has the largest membership of all of the SIGs, serving a broad range of industries in project management for the information systems sector.

not obtaining sufficiently large representations of the various forms of distributed project organizations would have been considerably higher. Third, it is very likely that surveys with similar focus have been mailed to this sampling frame in the past, leading to survey fatigue among the membership.

To check for the presence of non-response bias and potential differences across the two sampling groups, we used the extrapolation method proposed by Armstrong and Overton (1977). Their 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 only after multiple contacts. Using this procedure, data from each of the sampling groups was split into two sub-samples: the first sub-sample representing those responses obtained after the first contact and the second corresponding to responses obtained after sending reminder e-mails. Statistical t-tests performed across early and late responders in each sampling group based on demographic variables did not reveal any significant differences; non-response bias was not a problem with the data. Further, tests on demographic differences and project performance outcomes across the two sampling groups did not indicate any significant differences. The two sampling groups were 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 was 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. 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% were either team members or held specialist roles such as a technical lead or a quality assurance or business analyst within a project. 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% were affiliated with project client/client firm, and the remaining 13% were affiliated with an external consultant. The average total work experience of respondents was 21.2 years, out of which an average of 11.5 years had been spent in a project management role. Among projects, 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 (75%) of the project client/client firms were located in North America. 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, the U.S. had the highest representation of project clients/client firms at 65% of the total sample. Among projects that spanned country boundaries (Offshoring and Offshore-Outsourcing projects), a majority (65%) were carried out by project teams/vendor firms located in Asia (nearly 56% in India alone), while North America was a distant second, accounting for 17% of the sample.

4.3 Variables and Model Specification

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, providing details regarding their measurement. Table 1 lists the key variables (and their underlying measurement items) in the production and the technical efficiency functions.

----------------- 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 α = 0.90) derived from the mean of five items which 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 were recorded on a 7-point Likert scale (1 = Significantly Worse, 7 = Significantly Better).

$$\text{Project Performance}_i = \frac{\text{Adherence to Schedule}_i + \text{Adherence to Budget}_i + \text{Adherence to Quality}_i + \text{Technical Performance}_i + \text{Overall Satisfaction}_i}{5}$$

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, of course, indicative of the project's input in the form of manpower or effort, and also of the resource availability in a project.

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

Project Budget: Project budget (*Budget*) is measured as an ordinal categorical variable that represents the total budgetary allocation for 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 controlled for the past experience (*PastExperience*) of the project team in handling similar projects, as this could be a critical factor affecting project performance (Haas 2006). Four items (Cronbach's α = 0.75) were used to capture the experience of project team with past projects of the same project organization type, scope/size, and 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 (*TECHUNC*) and requirements uncertainty (*RUUNC*) constructs were 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 α = 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 questionnaire items reflecting requirements uncertainty (Cronbach's α = 0.85) measured the degree of stability of project client requirements at various stages in the project. Architectural uncertainty (*ARCHUNC*) for a project was measured using three items (Cronbach's α = 0.76) that measured the difficulty involved in decomposing a project into individual task modules and in clearly identifying interdependencies across the task modules. The responses for each item were recorded on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

4.3.3 Control Variables in the Production Function

In addition, we controlled for characteristic variations across projects that could potentially explain performance differences. The different project categories in the sample (Hardware, Software, and Infrastructure) each have different information requirements and challenges for team members. Differences in these characteristics have the potential to 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 2002), 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 by including dummy control variables for selected industries that have high representation in the sample[11]: (*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). Further, given that the majority of the project teams were located in North America, we controlled 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 controlled 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).

[11] 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 of five project organization types to describe their project: Collocated Insourcing, Distributed Insourcing, Outsourcing, Offshoring, or Offshore-Outsourcing. To ensure that the respondents understood the meaning of each project organization type and answered appropriately, brief definitions were provided 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; and 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 outset, factored into the 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 were pursued in a project. Some key practices that characterize 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 encouragement of 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 was measured along two key dimensions: (i) whether transition of members within the project team was carried out satisfactorily; and (ii) whether team members stayed on the project for a satisfactory duration of time. A total of three items were 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 α = 0.80) were 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, beyond the effect of project input variables and purely random shocks. The support we find 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.

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

The technical efficiency component, U_i, was initially specified and estimated as a non-negative truncation of the normal distribution with an unknown mean μ and variance σ_u^2, i.e., $U_i \sim$ iid $N^+(\mu, \sigma_u^2)$. However, the model likelihood function failed to converge under this specification. Therefore, we proceeded with a more parsimonious assumption wherein the technical efficiency component of the production function is assumed to be an independently and identically distributed half-normal random variable with mean zero and unknown variance σ_u^2 (i.e., $U_i \sim$ iid $N^+(0, \sigma_u^2)$). Further, due to missing values across some of the key input variables in the production function, we followed a conservative approach, estimating the production function for the sample of projects for which we had complete information across all variables. This step 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 and control variables has significant explanatory value for the output variable. More importantly, the chi-square likelihood test for negative skewness of residuals is strongly significant ($\chi 2 = 65.36$, $p < 0.01$), indicating the presence of a systematic technical efficiency component in the production function. Taken together, the above results not only support the appropriateness of our specification, but also lend credence to the key argument in our study – i.e., 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 function 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 of only tangential value (Greene 2003, Coelli et al. 2005). Therefore, we shift our focus toward an examination of the managerial factors that impact the technical efficiency of a project. The specification of the technical efficiency function is as follows:

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

where, U_i lies between 0 and 1 and W_i's are independently distributed and 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 the 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 and technical efficiency functions.

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

Hypothesis 1 states 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 estimates 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) are associated with lower technical efficiency as 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, these results lend partial support for Hypothesis 1.

Hypothesis 2, which proposes a positive association between the amount of face-to-face interaction in a project and its technical efficiency, is supported (δ_5 = 0.068, p < 0.05). This result indicates that an increase in face-to-face interaction in a project is, indeed, associated with a 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 technical efficiency. The results of our analysis support Hypothesis 3 (δ_6= 0.188, p < 0.01), indicating that the greater is the use of risk management practices in projects, the greater is their technical efficiency. Hypothesis 4, which asserts a positive association between the use of agile project management practices in a project and its technical efficiency, is supported (δ_7= 0.177, p < 0.01). Finally, Hypothesis 5, which theorizes a negative association between employee turnover in projects and the technical efficiency of those projects, is also supported (δ_8= -0.155, p < 0.01).

Although not formally hypothesized, we carried out additional analysis to examine whether the technical efficiency of project organizations distributed across firm boundaries differed from those that were distributed across country boundaries. This analysis involved multiple pair-wise comparisons of parameter estimates, with each pair-wise comparison consisting of pairs of distributed project organizations which differed from each other in terms of distribution across a single boundary (firm or country), holding the other boundary invariant. Specifically, the effect of firm boundaries among distributed project organizations is determined by comparing parameter estimates between DI and OUT

(δ_1- δ_2) and OFF and OUT (δ_3- δ_4). Using a similar approach, the effect of country boundaries is determined by comparing parameter estimates between DI and OFF (δ_1- δ_4) and OUT and OFFOUT (δ_3- δ_5).

Our analysis here indicates that the effect of firm boundaries on technical efficiency across distributed project organizations is statistically insignificant [i.e., (δ_1- δ_2) = -0.084, p > 0.1 and (δ_3- δ_4) = -0.118, p > 0.1]. In contrast, each pair-wise comparison for determining the effect of country boundaries *was* statistically significant [i.e., (δ_1- δ_4) = -0.378, p < 0.05 and (δ_3- δ_5) = -0.413, p < 0.01]. Collectively, these pair-wise comparisons indicated that the information processing, transactional, and resource utilization difficulties encountered by the distribution of projects across country boundaries have dominant negative effects on the technical efficiency of projects, as compared to distribution of projects across firm boundaries.

5.3 Robustness of the Model Estimation Results

We also carried out additional analyses to check the robustness of our 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 (that is assumed to be distributed as a non-negative truncation of the normal distribution) and a random error component (that is always assumed to be distributed as a two-sided normal distribution). To check whether our results were robust enough 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 additional 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 changes in model specification led to results that differed from our original findings. 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 find any major differences between results from this analysis and our original findings (see Appendix for details).

Comparison with trans-log specification of the stochastic production function: The production function in this study is specified using the Cobb-Douglas functional form. Using the Cobb–Douglas specification implies an elasticity of substitution of unity between the input factors by construction, and ignores the possibility of varying elasticity of substitution between input factors. Further, if the true structure of the production function is more complex than the Cobb-Douglas specification, the unmodeled complexity will enter the error term, leading to biased estimates of the technical efficiency. A popular alternative to the Cobb–Douglas specification is the trans-log specification which takes a second-order approximation to the underlying production function, and is more flexible in terms of elasticities of substitution. Specifically, seven quadratic terms and 21 second-order interaction terms for the seven input variables were entered additionally into the original Cobb-Douglas specification to represent the more general trans-log specification. The likelihood function initially failed to converge under the assumption that the composed error term follows a normal–truncated normal distribution. The more parsimonious assumption wherein the composed error term follows a normal–half-normal distribution was used and the likelihood function converged. The estimated elasicities of the technical efficiency function were comparable to those obtained from the Cobb-Douglas specification, thereby highlighting the robustness of our results to alternative specifications.

6. Discussion

6.1 Variation in Technical Efficiency across Project Organization Types

Results from our study indicate that the technical efficiency of a project varies with the choice of the type of 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 the technical efficiency of Collocated Insourcing and Distributed Insourcing project organizations, our results 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. The sharp decrease in the mean technical efficiency estimates for Offshoring and Offshore-Outsourcing project organization compared to that for Outsourcing project organization is particularly notable and emphasizes our finding (on p. 21) that the distribution of projects across country boundaries poses substantial coordination and resource utilization problems when compared to projects distributed across firm boundaries.

It should be noted that these findings do not imply that distributed project organizations, particularly Offshoring and Offshore-Outsourcing project organizations, cannot achieve levels of technical efficiency that are comparable to those of 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 these inferences by illustrating increased variation in technical efficiency estimates for Offshoring and Offshore-Outsourcing project organizations.[12]

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

[12] We caution that the above findings based on mean technical efficiency estimates should not be extrapolated to imply any trends in profitability or the actual value of project outcomes across the different types of project organization. Technical efficiency of a project simply reflects the ability of a project to convert project inputs into project outputs. Thus, a Collocated Insourcing project with high technical efficiency compared to an Offshore-Outsourcing project may not necessarily be more profitable to the project client, because of the effect of external factors such as labor arbitrage.

6.2 Impact of Project Management Factors on Technical Efficiency

From the empirical analysis results, we infer 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 underscores the point that frequent face-to-face interaction between a project team and the project client can 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. In contrast, minimal or no face-to-face interaction can leave project teams in distributed settings highly vulnerable to process losses and performance problems (Gibson and Cohen 2003, Lipnack and Stamps 2000). The following anecdotal example of an information technology project is illustrative of potential inefficiencies arising from lack of in-person 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: a 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 agile management practices result highlights the benefits of pursuing an iterative and incremental approach to project execution with collective involvement of both the members of a project team and the project client over a traditional sequential/waterfall approach to project execution. Similarly, a heightened awareness of project risks and the pursuit of project management practices that anticipate and plan for 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 results confirm 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 related to improvements in the efficiency of project execution, there is little empirical support for this relationship documented in the literature. Further, the magnitude and the statistical significance of this relationship in our results stress the notion that employee turnover could indeed be a barrier to efficient project execution and so managers should focus intently on minimizing not only the outflow of important human resources from a project, but also avoiding frequent personnel transitions across projects.

To examine whether the impact of project management factors on technical efficiency varies across the different types of project organizations (e.g., if there is a 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 that managers in such project organizations emphasize risk management, agile project management, and timely face-to-face interaction while making a concerted effort to reduce employee turnover.

7. Conclusion

This study was motivated by the growing realization that projects (such as new product development and information technology projects) are increasingly distributed across firm and geographical boundaries and concerns about the efficiency of project execution 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: 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. Our empirical analysis was based on primary data collected from a mix of more than 700 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 on the execution phase of projects and providing insights into how the project execution phase can be managed to improve the efficiency of project execution. While anecdotal and empirical evidence documenting the performance outcomes of projects in outsourcing and offshoring contexts exist, relatively little has been previously documented by way of either measurement of project efficiency or factors that are 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, exhibit significantly lower technical efficiency compared to Collocated Insourcing project organization. We also identify project management practices that are 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 while employee turnover is negatively associated with the technical efficiency of a project.

This study also makes an important methodological contribution to the literature on project evaluation. The benefit of using a frontier analysis technique such as SFA over traditional linear models arises from the fact that it provides individual project-specific estimates of technical efficiency for the projects in the sample. This provides us an opportunity to not only observe the relative ranking of projects but also allows us to compare and contrast estimates of technical efficiency across categories of projects (such as those representing the project organization types in this study). While a few studies in the extant literature have used Data Envelopment Analysis (a non-parametric frontier analysis technique) to undertake comparative evaluation of projects (e.g., Banker et al. 1991, Verma and Sinha 2002), the use of SFA provides an additional advantage over such studies, in that, it allows the parametric specification of the relationship between the technical efficiency and structural and infrastructural project factors (to be estimated jointly with the production function), thus allowing direct tests of hypothesis for evaluating factors affecting technical efficiency.

As with any study, ours, too, has limitations and appropriate caution should be exercised in interpreting the results. First, the use of a single informant for collecting information on a project is a limitation. Since, in this study, 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 are seldom found within a single firm. We reached out to professional management associations (PMI-ISSIG and PMI-NPDSIG) for data collection to ensure that we had a sampling frame that included project management professionals from different firms in different industries and from different countries. This did, however, limit 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 affiliations to their project (project client/client firm, 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 is related to the use of a cross-sectional data set (such as ours) in specifying and estimating stochastic frontier models (Schmidt and Sickles 1984). Specifically, the maximum likelihood estimation of the stochastic production function and the technical efficiency function makes strong distributional assumptions on the composite error component, and also assumes that the technical efficiency error component is independent of the input vectors. Such assumptions may lead to estimates of technical efficiency with less desirable statistical properties in cross-sectional data sets. These issues are minimized when panel data is available; repeated observations on a sample of projects can substitute for both strong distributional assumptions as well as the independence assumption (Kumbhakar and Lovell 2000).

The third limitation of our study relates to a larger representation of information technology projects in our study sample compared to physical product development projects. Since tests on demographic differences and project performance outcomes across the PMI-ISSIG and PMI-NPDSIG sampling groups did not indicate any significant differences, we combined the sampling groups to yield a total sample of 830 technology projects for conducting the analysis in this study. We believe that 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. A final 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 these 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 settings of this study) are being distributed across firm and geographical boundaries, the questions addressed in this study are both contemporary and consequential. And, we hope that this study will motivate other researchers and practitioners to pursue similar lines of inquiries.

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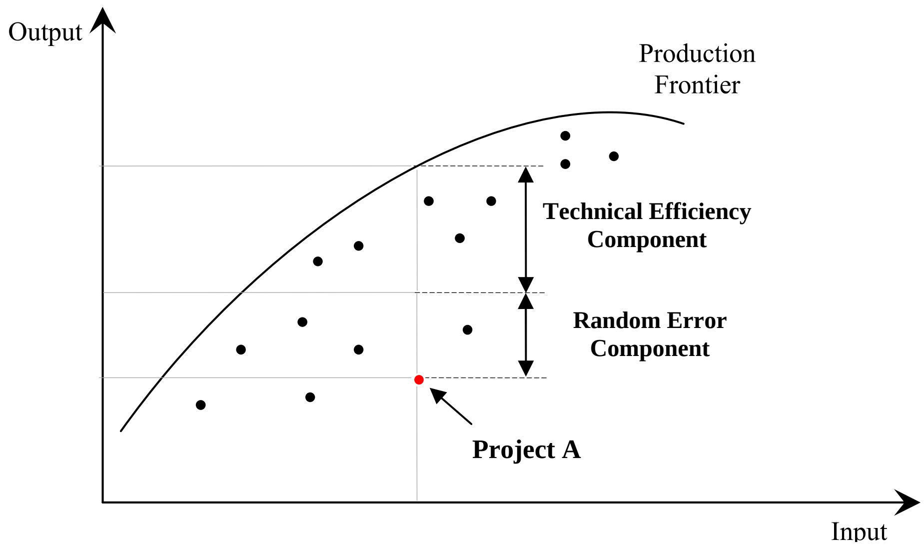

Figure 1: Decomposition of the error term in the stochastic frontier analysis (SFA) models

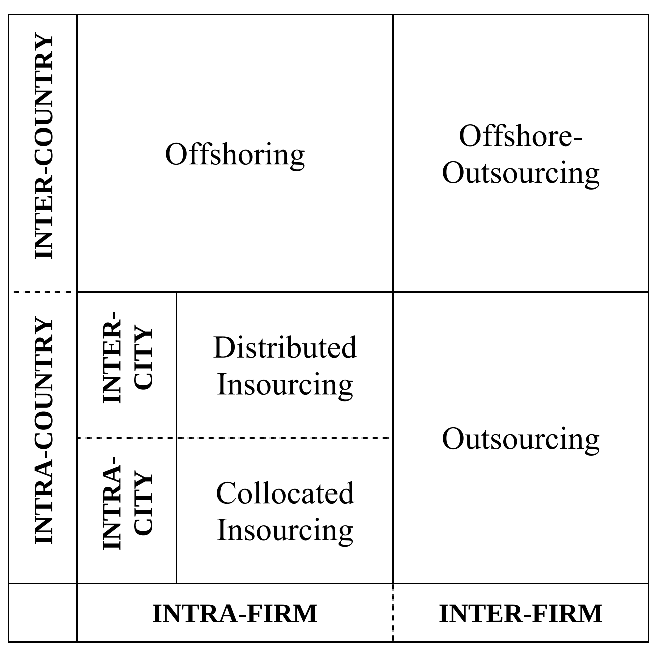

Figure 2: Project Organization Types

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

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

Output Variable: 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.	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	0.604	0.936
Outsourcing **[OUT]**	152	0.807	0.130	0.515	0.932
Offshoring **[OFF]**	54	0.739	0.150	0.435	0.920
Offshore-Outsourcing **[OFFOUT]**	120	0.697	0.184	0.299	0.921

† p< 0.1 , * p < 0.05,**p < 0.01

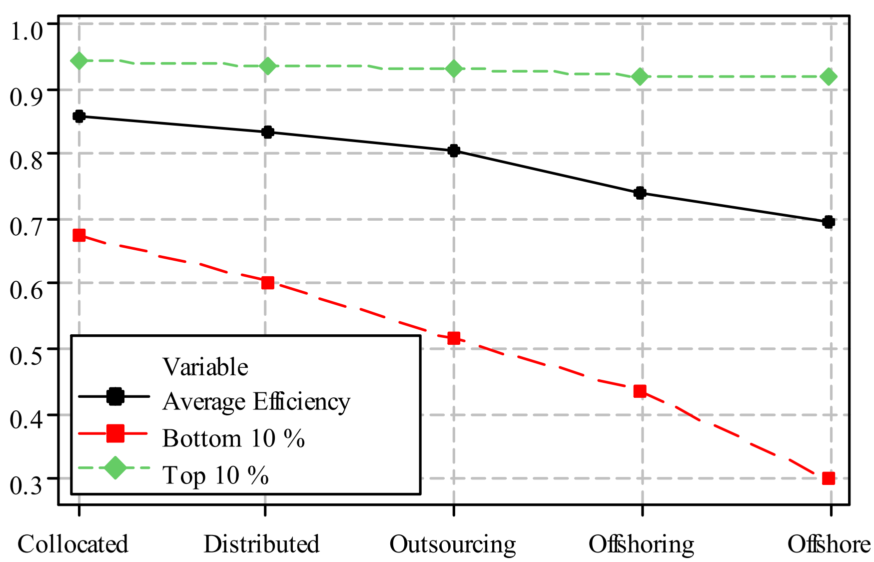

Figure 3: Variation in technical efficiency levels across project organization types

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