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Guodong Gao
University of Maryland

Anand Gopal
University of Maryland

TO CMM OR NOT TO CMM? ANTECEDENTS AND CONSEQUENCES OF CMM CERTIFICATION IN THE INDIAN OFFSHORE SERVICES INDUSTRY

Anandasivam Gopal
RH Smith School of Business
University of Maryland
agopal@rhsmith.umd.edu

Guodong (Gordon) Gao
RH Smith School of Business
University of Maryland
ggao@rhsmith.umd.edu

Abstract

Third-party process certification programs such as the Capability Maturity Model (CMM) and the ISO 9000 set of standards have been popular in the IT outsourcing industry as a means of differentiation and quality assurance. Specifically, prior theory in signaling indicates that in markets where there is significant information asymmetry between vendors and potential clients, firms perceive value in acquiring certification so as to provide a reliable signal of higher quality and better processes. Consequently, firms that are certified should experience significant benefits accruing from both their supply and demand sides. We test these hypotheses in the context of the Indian offshore IT services industry on firm-level panel data on 66 vendor firms collected from 1997 to 2002. We first propose a discrete choice model that examines a firm's decision to acquire CMM Level 3 certification. Subsequently, we study the effects of CMM certification on the firm's costs and exports. Our results indicate that in accordance with signaling theory, more cost-effective firms and export-oriented firms are more likely to acquire certification. In addition, CMM Level 3 certified firms show significant improvements in exports. Certified firms also see an improvement in their cost efficiency after obtaining certification. Our analysis indicates that the business value of CMM certification in the Indian offshore industry appears to be driven by significant demand-side benefits. This is consistent with prior work in signaling that shows the benefits of indicating better service and quality to potential customers. This helps in reducing the information asymmetry between the firm and clients in the offshore domain, thereby leading to enhanced firm performance.

Keywords: offshoring, outsourcing, information asymmetry, CMM, certification, firm performance

Introduction

The rise of the offshore IT services industry has been attributed to the significant cost savings that accrue to firms that outsource their IT needs to countries such as India and Ireland. Although these cost savings exist, the impact of the geographical, cultural and organizational boundaries that separate clients and vendors in this domain is also pervasive. These boundaries enhance the risks inherent in offshoring activities since they intensify the information asymmetry between clients and vendors. Specifically, potential clients in offshore markets have inadequate information on which to judge the capabilities of vendors, and vendors have weak signals to use in demonstrating their real capabilities to potential clients. There is, therefore, a need for third-party intermediaries who can provide a reliable signaling service to clients about vendor capabilities. Similarly, vendors need a mechanism by which they can generate such signals of competencies in order to attract potential clients.

This signaling need is satisfied to some extent by the development and adoption of voluntary management certification programs such as the ISO 9001 standard (ISO 2003) and the Capability Maturity Model (CMM) proposed by the Software Engineering Institute (SEI; Herbsleb et al 1997). These organizations propose standard or normative models for managing processes within organizations; these models are built on disciplined processes, documentation, defined management practices and a focus on quality. In theory, adopting organizational processes that adhere to the normative models proposed by the ISO and the SEI should provide organizations with significant internal efficiencies, resulting in increased control over project costs, cycle times and quality (Herbsleb et al 1997; Casadesus et al 2001). In addition, vendors who are certified as compliant with these standards also provide potential clients with a reliable signal of the vendor's capabilities, thereby obtaining demand-side benefits for the vendor (Terlaak and King 2006; Corbett et al 2005).

Considerable research exists that examines both the antecedents of the ISO 9000 certification decision (e.g., Anderson et al 1999) as well as the consequences of being ISO certified (e.g., Corbett et al 2005); however, this research focuses mostly on the manufacturing sector. There is little work that has addressed the role of certification programs in the services sector. The CMM, in contrast, is newer than the ISO standards and has been designed around the software development and service delivery process with roots in the US Department of Defense's software acquisition problems (Herbsleb et al 1997). Unlike the ISO, which originated in manufacturing and focused on product uniformity and conformance to provided specifications, the CMM is meant to optimize and continuously improve processes that deliver quality software (Herbsleb et al 1997) and is therefore uniquely suited for the IT services sector. Given the paucity of research in certification programs within the services sector, we chose to address this gap by focusing on the antecedents and consequences of CMM certification in the IT services industry.

There are two significant questions that we address in this paper. First, we examine the choice that some firms make to acquire CMM certification from third-party intermediaries. Specifically, we use prior research in signaling theory (Spence 1973) and institutional theory (DiMaggio and Powell 1983) to hypothesize the effects of firm characteristics and capabilities on the decision to acquire certification. The second question we study is that of the effects of CMM certification on a firm's performance. The benefits of being certified CMM-compliant should include both supply-side benefits—characterized by higher internal efficiencies—and demand-side benefits—measured by increased revenues. We study whether these benefits do indeed accrue to CMM-certified firms, in contrast to prior work, which has focused mostly on supply-side efficiencies (e.g., Krishnan et al 2000).

We focus our analysis on the Indian offshore IT industry. The Indian software industry has emerged in the past few years as a market leader in the IT services domain, with exports of $18 billion in 2005 and an annual growth rate of approximately 40% (www.nasscom.org). More important, the Indian industry has adopted voluntary management certification programs, such as the CMM, with fervor. Of the 70 firms in the world that have been assessed at the highest level of the CMM (CMM Level 5), 50 are in India (King 2003). The Indian offshore industry therefore forms a perfect candidate for the study of both the CMM certification decision as well as the resulting benefits. We test our hypotheses on firm-level panel data from Indian offshore vendors from 1997 to 2002..The use of panel data (as compared with cross-sectional data) enables us to make stronger causal arguments about CMM certification and the associated ex post benefits.

Our research makes three primary contributions to the literature. First, we extend existing micro-level (project-level) research on the supply-side benefits of CMM certification to the level of the firm. Through panel data, we are able to make stronger causal statements of the effects of CMM certification. Second, we extend prior research that studied certification programs in the manufacturing sector to the services sector. Little work addresses these issues in the IT services sector, and our work is the first, to our knowledge, to focus on this vital sector of the economy. Third, we add to the small but growing body of research on the Indian offshore industry, a leader in the outsourcing domain. We describe the background theory and research hypotheses in the next section.

Background Theory and Research Hypotheses

The Capability Maturity Model

The Capability Maturity Model (CMM) was developed by the SEI and the Mitre Corporation to help organizations improve their software *processes*. A fundamental factor in software development cost and productivity is the inability of firms to manage the software process efficiently (Paulk et al 1993). The benefits from better methods, tools and systems and from competent team members cannot be realized in an undisciplined, chaotic process. A "software process" is thus defined as a set of activities, methods, practices and transformations that people use to develop and maintain software and associated products (project plans, design documents, code) (Paulk et al 1993). *Software process maturity* is the extent to which a specific process is explicitly defined, managed, measured, controlled and made effective. Maturity implies a potential for growth in capability and indicates both the *richness* of the organization's software process and the *consistency* with which it is applied in projects throughout the organization.

The CMM model therefore provides software organizations with guidance on how to gain control of their processes for developing and delivering software services. The CMM consists of 5 *maturity levels* (Paulk et al 1993). Organizations with software processes that are ad hoc and chaotic are categorized as Level 1 firms, while mature and disciplined processes earn a Level 5 ratification. Generally, significant improvements in processes are required to be certified at Level 3 and Level 5 since these represent sufficiently different approaches to managing projects (Eickelmann 2003; Keeni 2000). In addition, firms that are ISO 9000 certified are considered to be roughly equivalent to Level 2 of the CMM (Paulk 1995). As a signal of process excellence, a Level 3 certification represents a significant first step toward process maturity, while Level 5 appears to be the final goal. CMM certification is typically carried out by CMM auditors and consulting firms trained by the SEI. Anecdotal evidence shows that mean time to transition from Level 2 to Level 3 is 24 months, with a median cost of $1375 per engineer (Herbsleb et al 1997), although Indian firms tend, on average, to ascend the maturity levels much faster than 24 months (Issac et al 2004).

Existing research on the impact of CMM-based software processes on performance have focused more on project-level benefits than on firm-level benefits. Most of these project-level performance benefits have focused on internal efficiencies, such as project costs and cycle times. Krishnan et al (2000) reported that adoption of processes prescribed within the CMM was positively associated with quality and productivity on a selection of software projects. In a similar vein, Harter et al (2000) provided evidence that CMM is positively associated with project cycle times and productivity. Other case studies in the literature have reported on the beneficial impact of CMM on productivity, accuracy of effort and cost estimates (Eickelmann 2003); product quality (Keeni 2000); increased employee productivity; and staff morale (Herbsleb et al 1997).

Although there is some evidence of the impact of CMM certification on internal efficiencies, there is little evidence that these internal efficiencies translate into better firm-level performance. An open question remains, therefore, as to whether internal efficiencies emerge at the firm level for certified firms. Moreover, one of the criticisms leveled at the CMM and other certification programs such as ISO 9001 is that the costs incurred by organizations in gaining certification and the overheads imposed on the organization are not offset by enhanced financial performance or market power (Issac et al 2004). Lack of evidence of the demand-side effects of CMM certification is, thus, a significant gap in the literature.

Antecedents to CMM Certification

One of the central benefits of process certification programs is the ability to communicate the capabilities of the organization to potential clients. Prior research in the ISO 9000 context has suggested that certification provides a credible signal of enhanced processes and quality that serves to distinguish a firm from its competitors (Anderson et al 1999). The signal addresses the information asymmetry that exists between clients and vendors in the offshore market that makes it hard for clients to gauge the capabilities of potential vendors (Banerjee and Duflo 2000; Akerlof 1970).

Spence (1973) analyzes the role of signaling in the decision to acquire a college degree and shows that the value of the signal is predicated on the cost of acquiring the signal for various parties. Analogously, in the offshore context, clients typically have little information to use in distinguishing high-quality vendors from low-quality vendors. Therefore, if any signal is to efficiently distinguish between the high-quality and low-quality vendors, the cost of acquiring the signal must be *low* enough for the high-quality vendor to do so but *high* enough to deter the low-quality vendor from doing so. The costs associated with acquiring certification are typically related to redesigning the processes within the organization, focusing efforts on metrics-based project and portfolio management and creating the necessary feedback loops to channel process-based decision-making back into the development process (Herbsleb et al 1997).

The primary focus of the CMM is to enhance internal efficiencies within the firm, that is, to improve cost effectiveness, reduce cycle times and enhance employee productivity (Paulk et al 1993; Herbsleb et al 1997; Issac et al 2004). In effect, these efficiencies should typically manifest themselves in better control over the cost of software development activities, given constant quality[1]. The signaling argument therefore indicates that firms that perform better than their competitors on operating costs will find it easier to acquire CMM certification. In contrast, firms that are not as competitive will find the costs of adopting the CMM prohibitive. Similar trends have been observed in prior literature on the adoption of the ISO 9000 (Anderson et al 1999; Heras et al 2002) and ISO 14001 environmental standards (Toffel 2006; King et al 2005). Therefore, we hypothesize the following:

H1: The lower the average cost of operations in an organization, the higher is the propensity to acquire CMM certification

The offshore nature of the Indian IT services industry makes information asymmetry between the vendor and potential clients more pervasive than for same-country service providers. Clients in foreign countries have limited abilities to observe quality processes or even evaluate the validity of client references from vendors. In such contexts, the perceived value from third-party certification would be higher, as shown in the case of the ISO 14001 environmental standard (King et al 2005). Indian vendors that have a greater presence in the exports market will find greater value from CMM certification and hence will be more likely to acquire certification. Market leaders specifically will find the value from acquiring certification particularly attractive, given the possible effect of the signal on their revenue potential from new customers as well as increased revenues from current customers through premium pricing (for possibly higher quality services).

The impetus to acquire certification could also emerge from strong institutional forces operating in the offshore IT industry in India. Institutional theory describes the institutional forces that drive organizations to adopt practices that confer legitimacy on them (DiMaggio and Powell 1983; Meyer and Rowan 1983). These forces can be applied on organizations by the competitive environments that the organizations operate in, stake-holders such as customers and by regulatory agencies. The perceived value of CMM is high in Western countries such as the United States since it provides clients with necessary information that may not be easily available otherwise. In many cases, CMM certification is a pre-requisite for bidding for business in American and European markets (Keeni 2000). Therefore, organizations with a focus on these markets will find the payoffs from certification much higher than organizations that do not operate in the offshore market. Therefore, we propose:

H2: Organizations with higher software exports will have a higher propensity to acquire CMM certification.

Performance Benefits from CMM Certification

An important part of Spence's (1973) signaling theory is based on the reasoning that providing potential employers with a credible signal will lead to a wage premium that offsets the cost of acquiring the signal. Whether CMM certification does indeed result in realized benefits to the organization is, however, an empirical question. Prior research on the performance benefits that result from being certified as meeting management standards such as ISO 9001 and ISO 14001 has shown (mostly based on surveys) mixed results (Casadesus et al 2001; Naveh and Marcus 2004; Terziowski et al 1997; Singels et al 2001). More recent research using more objective performance data from

[1] The assumption of constant quality may not be true. However, we address this issue in the hypotheses on the effect of CMM on firm performance. The underlying issue resolved by signaling is that true quality is not observable due to information asymmetry. Therefore, certification and high quality are co-determined and indistinguishable in the offshore context. Certification is used as a proxy for high quality and/or disciplined processes.

firms has shown significant benefits from adopting the ISO 9001 standard (Corbett et al 2005; Terlaak and King 2005) and ISO 14001 (Toffel 2006).

Researchers have postulated that process certification should have significant internal and external benefits to an organization (Casadesus et al 2001). The internal benefits from CMM certification should address the efficiency and discipline with which the organization is able to provide services to its clients. Therefore, the benefits from increased software process maturity should be associated with enhanced control over development costs and cycle times (Herbsleb et al 1997, King 2003; Keeni 2000; Issac et al 2004). Prior work at the project level has also indicated that teams that incorporate CMM-related process management activities show significantly better efficiency outcomes (Krishnan et al 2000; Harter et al 2000). Therefore, we hypothesize the following:

Hypothesis 3: CMM certification will lead to lower average operating costs, all else being equal.

Extending the signaling arguments from Spence (1973), if the primary motivation of CMM certification is to provide a signal to potential clients and reduce information asymmetry in the market, the benefits should accrue on the firm's demand side (Toffel 2006; Casadesus et al 2001). Therefore, certified firms would expect to see greater revenues and market power as a result of acquiring CMM certification. Vendors can also use certification as a proxy for quality of their services, which is hard to measure and communicate at the aggregate firm level. Indeed, some of the demand-side benefits reported from certification include enhanced revenues, exports and market share, all else being equal (Herbsleb et al 1997; Keeni 2000). This reasoning is analogous to prior research that has shown significant demand-side benefits from instituting award-winning TQM practices within firms (Hendricks and Singhal 1997). Therefore, we hypothesize the following:

Hypothesis 4: CMM certification will lead to greater exports, all else being equal.

It is worth noting that *both* demand- and supply-side benefits can accrue to a firm from adopting practices that lead to CMM certification. The focus on improving internal processes will enable a firm to become more internally efficient, while the signaling benefits will enhance external market position. Our hypotheses, therefore, also provide some evidence for whether the signaling arguments dominate over the internal efficiency motivations with respect to CMM certification in India. Specifically, if hypothesis 3 is not supported while hypotheses 4 is supported, it would appear that firms acquire certification mostly to provide clients with information about themselves but do not change their internal economies in any significant way. Our analysis, therefore, indirectly provides some evidence of possible sources of the business value of CMM certification.

Data Collection and Variable Operationalization

Data Sources

The data for this study were gathered and collated from two primary sources. The first source was NASSCOM, an industry-level trade body consisting of software development organizations in India. Our main data sources are NASSCOM Membership directories, published annually between 1996 and 2003. The directories provide some important operational and financial information on NASSCOM member companies. We augment the data from NASSCOM by acquiring profitability and cost information on the Indian IT industry from the Center for Monitoring the Indian Economy (CMIE, www.cmie.com). CMIE is a think-tank that collects public domain data on firms from different sectors of the Indian economy. The CMIE data are only available for publicly listed companies in India; information on foreign subsidiaries and private firms is not available.

The NASSCOM directories typically cover all the member organizations, which number approximately 600 per year. However, most of these firms are small entities with low representation in the exports market. The Indian IT services industry is characterized by a heavy concentration of market power in a few firms that dominate the industry. *DataQuest*, a leading Indian IT publication, reported in its survey of the IT industry in 2005 that the top 5 firms accounted for over 30% of the software exports[2]. The top 20 firms accounted for 53% of the exports. Therefore, in order to gain an understanding of the industry it is adequate to consider a smaller set of firms.

In order to identify this smaller set of relevant firms for this study, we used the *DataQuest* rankings of the top 200 firms in India in the year 2000 according to sales. From the top 200, we omitted hardware vendors, consulting firms

[2] http://www.dqindia.com/dqtop20/2005/artdisp.asp?artid=72754&secid=

and infrastructure providers such as ISPs and telecom service providers, leaving us with 95 firms. Of these firms, 66 were successfully matched to the NASSCOM directories over the period of 1997–2002, leading to a usable sample of 344. There was no financial or operational information on the remaining 29 firms available in the NASSCOM publications, possibly because they were all either private firms or wholly owned subsidiaries. The 66 firms in our sample account for approximately 65% of the Indian IT services exports market, providing us with a highly representative coverage of the exports industry. Of the 66 firms, operating cost and profitability information are only available for 44 firms from CMIE, providing for a total of 220 observations.

It is sometimes the case that multiple locations of the same firm have different CMM certification levels. Anecdotal evidence from India suggests that most subsequent certifications are at least on par with the first certification, that is, if a firm sets up a development center in a different location, the certified processes from its first certified location are usually institutionalized at the new location (Keeni 2000). Therefore, we focus on the first reported CMM certification, which is consistent with prior research on the study of certification (Corbett et al 2005; Simmons and White 1999).

Variable Definitions

Dependent Variables

CMM Level: Organizations are assessed at CMM Levels 1 through 5, based on their development processes. In the Indian context, Levels 1 and 2 are often not reported (Keeni 2000). The first significant signal of CMM certification occurs when organizations are assessed at CMM Level 3. Paulk (1995) describes CMM Level 2 as reasonably equivalent to ISO 9001 certification; hence Level 3 represents a good starting point for studying CMM certification. The next significant stage in process maturity is at Level 5, which is relatively rare and is not always considered a desirable level of maturity (Eickelmann 2003). There is some evidence to suggest that many clients and vendors consider the overheads of CMM Level 5 to be inordinately high (Arora and Asundi 1999; Herbsleb et al 1997). Therefore, for the purposes of our baseline analysis, we treat the acquisition of CMM Level 3 certification as the key dependent variable. In later sensitivity analysis, we explore how our model extends to Level 4 and Level 5 certification as well. The attainment of CMM Level 3 is coded as a binary variable, with 0 for the years that the firm is not certified and 1 for the year in which it was attained and thereafter.
Exports: Captures the total IT exports from the firm in that financial year, in Indian rupees.
Average Cost: is reported by CMIE and is measured by the total cost of operations for the firm per year divided by total sales. This variable represents a size-normalized operational cost measure and is consistent with prior work (Hendricks and Singhal 1997; Corbett et al 2005).

Independent Variables

Market Share: is calculated as the ratio of the firm's exports to the total size of the Indian IT exports market for that year, available from NASSCOM.
Service-segment Specific Competition: NASSCOM reports the presence of each firm's service offerings in 14 vertical segments, such as transportation, retail sector, government and defense. The ideal measure for the firm's competitive environment would be based on a composite metric that takes into account the degree of competition and the resulting revenues in each of the firm's vertical segments (such as the Herfindahl index). However, that is not possible in the current situation since NASSCOM does not provide revenue data broken down by vertical segments. Therefore, we construct an index of competition faced by a firm in the following manner. To avoid confusion, we omit the time subscript below.
Define $S_{ij} = 1$ if firm i operates in segment j, 0 otherwise; i=1 to N, j =1 to K. Define M_j as the reciprocal of the count of firms that operate in each segment: $M_j = 1/\sum_{i=1}^{N} S_{ij}$. Thus, the smaller M_j, the more competitive that segment is. For each firm, the reciprocals of those segments are summed up according to the firm's operations scope across industries. This measure is biased upward for firms that operate in many segments. To eliminate this bias, we further divide the above measure by the number of vertical segments in which the firm operates. Thus the competition index for each firm is defined as $Competition_i = (\sum_{j=1}^{K} S_{ij} M_j)/(\sum_{j=1}^{K} S_{ij})$

Competitor CMM Certification: captures the percentage of a firm's direct competitors in different vertical segments that are CMM Level 3 certified or higher in that year.
ISO Certification: binary variable; 1 if the firm is ISO 9000 certified in that year and 0 otherwise. If ISO 9000 certified firms are roughly equivalent to CMM Level 2 (Paulk 1995), ISO 9000 certified firms should find it easier to acquire CMM certification since the incremental effort required is small.
Firm size: is a control variable and is measured by the total number of employees in that year (Corbett et al 2005, King et al 2005). The logarithm of this variable is used in the analysis.
Subscribed Capital: represents the total capital in Indian rupees that is currently being used by the firm.
Ownership: is binary and is 1 if the firm is a domestic (Indian-owned) firm and 0 if the firm is a wholly owned subsidiary or a joint venture. Foreign ownership could influence both the decision to acquire CMM certification and the resulting benefits.
Legal Structure: is binary and is 1 if the firm is a public firm and 0 if it is privately held.
Age: of the firm in years. This variable is logged to reduce the skewness.
Location: Although other cities have subsequently emerged as viable destinations for offshore work, Bangalore remains the hub of the industry. This variable is binary and coded 1 if the firm is located in Bangalore and 0 if elsewhere, to control for the possible spillover effect for firms clustered in Bangalore.
Time controls: We include two variables, *Year* and *Year_Squared*, to control for the unobserved trend in CMM certification over time, which might be associated with Indian macro economy and foreign trade factors. The results of using this quadratic form of time control are similar to using year dummies but allow us to capture the trends in CMM certification in a more parsimonious manner.

The summary statistics for the sample are provided in Table 1. 65.3% of the firms in our sample acquired CMM certification through the study period of 1997–2002.

Table 1: Summary Statistics

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
CMM Level 3	0.41	0.49	0.00	1.00
ISO 9001	0.75	0.43	0.00	1.00
Exports (In Rupees, Million)	1853.77	4130.57	0.44	38820.00
Revenues (in Rupees, Million)	2128.01	4491.89	1.80	41817.00
Market Share	0.01	0.02	2.00E-06	0.06
Service-specific Competition	0.04	0.01	0.02	0.06
Competitor CMM	0.48	0.21	0.13	0.83
Firm Size (Employees)	1449.77	2397.75	30.00	20410.00
Age (Years)	10.74	9.74	1.00	33.00
Location (Dummy)	0.28	0.45	0.00	1.00
Ownership (Dummy)	0.52	0.50	0.00	1.00
Legal Structure (Dummy)	0.54	0.50	0.00	1.00
Average Cost	0.850	0.176	0.207	1.858
Subscribed Capital (Rupees Million)	148.49	301.47	1.50	4600.00

Data Analysis

Our analysis is conducted in two stages. In the first stage, we estimate a CMM certification choice model. In the second stage, we estimate equations capturing the effects of CMM certification on supply- and demand-side performance.

We model the decision to acquire CMM certification as a discrete choice, and, hence, a logit model is suitable to test our hypotheses. We model the probability that a firm will acquire CMM certification in a given year, based on the independent and control variables identified in the previous section. Once the firm has acquired certification, modeling the certification decision in subsequent years is meaningless[3]. Therefore, we drop post-certification observations of the firm from the analysis. This methodology is consistent with methodology used by other researchers in similar settings, such as King et al (2005) and Toffel (2006). Using this approach, we are left with 208 observations from 64 firms. The following specification is used to model the certification decision:

$$Logit\ (CMM_{it}) = f\ (Average\_Cost_{i},\ Exports_{it}\ ,\ Market\text{-}Share_{it}\ ,\ Competition_{it}\ ,\ Competitor\_CMM_{it}\ ,\ ISO_{it}\ ,\ Size_{it}\ ,\ Legal_{it}\ ,\ Ownership_{it}\ ,\ SubCap_{it}\ ,\ Age_{it}\ ,\ Location_{it},\ Year_{t},\ Year\_Squared_{t}) + \varepsilon_{it} \qquad (1)$$

As pointed out before, average cost data are available for a subsample of firms in our dataset. Therefore, we estimate the model in equation (1) on this subsample first. As a robustness check, we also perform the analysis without the average cost variable on the full sample. We first estimate the above model using pooled logit regression. One drawback of the pooled logit specification is that it assumes independence across all observations. However, our sample is clustered in that it contains repeated observations from the same firms. An alternative method of capturing firm-level effects would be to use the fixed effects specification. However, the fixed effects specification is associated with a number of limitations. First, we lose too many degrees of freedom and do not utilize the variations across firms. Second, some of the independent variables (e.g., location) do not vary over time and therefore, it is not possible to separate out the effects of these variables from the fixed effect. In addition, prior research suggests that maximum likelihood estimators of non-linear, fixed effects specifications such as the logit in small samples and short panels are associated with significant bias (Hsiao 1996). The random effects model, on the other hand, imposes some strong assumptions on the variance–covariance structure of the error terms. It is assumed that the time-invariate idiosyncratic error term is uncorrelated with the independent variables in the model across all years (Wooldridge 2002). These assumptions might not be valid in our context since it is possible that the idiosyncratic firm-specific error term is correlated with the firm-level independent variables over time.

Therefore, we also apply the Generalized Estimating Equations (GEE) methodology developed by Liang and Zeger (1986), which extends quasi-likelihood estimation methods by allowing the use of flexible within-cluster correlations. By explicitly utilizing the correlation of error terms within firms across the panel, the estimation of the regression equation is more efficient (similar to a weighted least squares approach). The GEE method has been used extensively in the management literature (Audia and Greve 2006; Rhee and Haunschild 2006) as well as the epidemiology literature (Hanley et al 2003)[4]. As a subset of generalized linear models, GEE estimation requires the specification of the distribution for the dependent variable and a link function to explicitly model the relationship between the outcome and the covariates (independent variables). Since the CMM certification we study is binary, we choose the binomial distribution and use the logit function as the link function. We impose no constraints on the correlation structure of the error terms from repeated observations across years from the same firm; that is, the correlation matrix is unstructured. The results from both the pooled random effects logit model discussed above and the GEE estimation results are shown in Table 2. The results from the analysis on the smaller dataset (with average cost) are shown in the first two columns, while the analysis from the full dataset (without average cost) is shown in the third and fourth columns of Table 2. As further robustness checks, since our sample contains repeated observations from the same firms, we apply the clustered Huber-White robust standard errors, which allow for an arbitrary correlation of error terms among observations from the same firm, including heteroskedasticity and autocorrelation. Alternatively, we also specify an AR(1) structure in the error terms within same firms. Both results are reported in Columns 5 and 6 in Table 2.

Since we only model CMM Level 3 certification, the CMM variable is coded as a binary variable. However, it is possible to model different levels of CMM certification (Levels 3, 4 and 5) amongst the firms in our sample. We thus also apply an ordered logit regression to model the different CMM levels. The results from this analysis are consistent with the GEE and pooled logit results, and, therefore, we limit our discussion to the GEE results. Detailed results are however available from the authors upon request.

In the second stage of our analysis, we examine the effects of CMM certification on firm performance. To capture the effects of CMM certification on average cost, we include the one-year lagged CMM variable as an independent variable. We choose a lagged specification because there is likely to be a slight lag between the firm acquiring the CMM certification and its eventual impact on the firm's cost structure. Also, the effects of this signal on the firm's

[3] This would not be true if there were instances in which the firm lost its certification and subsequently chose to regain it. There are no instances of this occurring in our data, and anecdotal evidence suggests that this is generally not true in the case of CMM certification in India (King 2003).

[4] Interested readers are referred to Hardin and Hilbe (2003) for details on the GEE methodology.

demand side are likely to be lagged by a small interval as clients receive and recognize the value of certification. We also include firm size (number of employees) and subscribed capital in both equations to account for any possible scale effects on average cost. We omit the Legal Structure variable in the average cost equation since all the firms in this case are public firms.

$$Average\_Cost_{it} = f\,(CMM_{i,t-1},\ SubCap_{it},\ Size_{it},\ Age_{it},\ Ownership_{it},\ Location_{it},\ Year_t,\ Year\text{-}Squared_t) + \varepsilon_{it} \qquad (2)$$

The Hausman test was performed on the sample to test for whether the random effects or fixed effects specification would fit the data better. The test does not reject the random effects specification. Therefore, we report the random effects results along with the pooled OLS results in Table 3. The fixed effects results are also shown in Table 3 as a robustness check. We use the Huber-White robust standard errors to account for repeated observations of the same firm across time, which allows for both the heteroskedasticity and autocorrelation in unobserved errors from the same firm.

The demand side of the firm is captured in the total exports of the firm. The competition variables are included in this equation since these could have possible impacts on a firm's competitive positioning and thus on exports. In addition, a firm's average cost is also included as an explanatory variable since supply-side efficiencies could influence the firm's performance in the market (Hendricks and Singhal 1997). As in the previous case, we include the CMM term as a one-year lagged variable. The final equation estimated is:

$$Exports_{it} = f\,(CMM_{i,t-1},\ Competition_{it},\ Competitor\_CMM_{it},\ ,\ Average\_Cost_{it},\ Size_{it}, SubCap_{it},\ Age_{it},\ Ownership_{it},\ Legal_{it},\ Location_{it},\ Year_t,\ Year\text{-}Squared_t) + \varepsilon_{it} \qquad (3)$$

In this case as well, the Hausman's test does not reject the random effects specification. However, we report the pooled OLS, fixed effects and random effects results in Table 4 with the Huber-White robust standard errors[5].

Since the CMM certification is modeled here as a binary variable, it is possible that the CMM certification choice is endogenous (Maddala 1983). In other words, firms could choose to acquire certification based on expectations of higher performance, thereby making the certification decision endogenous. The lagged specification we adopt for the performance equations reduces the impact of simultaneity between the certification choice and performance. However, it is still possible that an omitted, unobserved variable could lead to biased coefficients in the performance models. The common methodology to correct endogeneity from unobserved variables is the two-stage Heckman procedure (Heckman 1978). However, there exists no clear extension of the Heckman method to panel data over two periods (Honore and Kyriazidou 2000). Other researchers have used the matched sample methodology (Toffel 2006) or the event study methodology (Corbett et al 2005) to overcome the possible effects of endogeneity. In the Indian context, a matched sample methodology is unfeasible due to the small number of representative firms that operate in the market. Our lagged CMM specification approximates the event study methodology by capturing the year of certification and the effects on firm performance within the next financial year.

In our case, it is still possible to use the Heckman procedure to examine whether our results are robust to possible endogeneity by focusing on yearly cross-sections, as has been done by King et al (2005). We choose the year 2000 cross-section as being the most representative of our panel dataset for several reasons. It is the mid-point of the time-period for which we have data. It represents a crucial turning point for the Indian industry as the reliance on Y2K projects was at an end. In addition, several firms acquired certification in the 1997–1999 time-period, thereby providing us with adequate coverage of certified and non-certified firms in the cross-section.

Results

We first discuss the results from the GEE model for the CMM certification choice model from Table 2. Hypothesis 1 pertains to average cost and is supported in our analysis (beta=-5.017, $p<0.05$). Firms with lower average costs show a higher propensity to acquire CMM Level 3 certification. In addition, Hypothesis 2 regarding exports is also supported (beta=0.969, $p<0.05$), showing that firms with higher exports will be more likely to acquire CMM certification. On average, an increase of one standard deviation in the firm's exports enhances the firm's probability

[5] We also estimate Seemingly Unrelated Regression (SUR) parameters for all our equations. The results are consistent with the random effects results and are available on request from the authors.

of acquiring certification by 14.8%. With respect to the control variables, we observe that the presence of competitors that are CMM certified strongly influences a firm's propensity to acquire certification (beta = 13.622, $p<0.05$). One standard deviation increase in Competitor_CMM tends to increase the propensity for a firm to adopt CMM by 27.6%.

Table 2: CMM Certification Acquisition
Dependent Variable: CMM Level 3 (binary)

	Logit	**GEE**	**Logit**	**GEE**	**Logit with Robust Cluster Error**	**Logit with AR(1) error structure**
Constant	-5.406	-4.220	-9.977***	-10.063***	-9.977***	-39.044***
	(3.337)	(2.898)	(2.648)	(2.552)	(3.207)	(10.609)
Average Cost	-4.625**	-5.017***				
	(2.014)	(1.803)				
Exports	1.028***	0.969***	0.585**	0.639**	0.585*	1.449**
	(0.388)	(0.349)	(0.263)	(0.273)	(0.312)	(0.612)
Market Share	15.819	14.233	9.785	2.096	9.785	14.780
	(42.025)	(36.998)	(31.110)	(29.966)	(26.807)	(70.154)
Service-specific Competition	30.032	50.394	18.807	37.200	18.807	78.522*
	(34.000)	(30.702)	(25.803)	(24.882)	(25.716)	(47.569)
Competitor CMM	14.087***	13.622***	9.794***	9.858***	9.794**	42.837***
	(5.253)	(4.459)	(3.781)	(3.385)	(4.260)	(14.873)
ISO 9001	1.140	1.210	1.887**	1.772**	1.887*	2.913*
	(1.032)	(0.935)	(0.889)	(0.837)	(1.062)	(1.502)
Subscribed Capital	-0.807**	-0.926***	-0.304	-0.370*	-0.304	-0.165
	(0.375)	(0.339)	(0.220)	(0.224)	(0.220)	(0.358)
Firm Size (Employees)	0.607	0.427	0.643	0.665	0.643	0.471
	(0.587)	(0.511)	(0.431)	(0.429)	(0.400)	(0.752)
Age (Years)	-0.804	-0.589	-0.613	-0.656	-0.613	-1.471*
	(0.742)	(0.592)	(0.422)	(0.426)	(0.396)	(0.887)
Location (Dummy)	0.306	0.218	-0.084	-0.154	-0.084	0.412
	(0.648)	(0.538)	(0.518)	(0.515)	(0.500)	(0.808)
Ownership (Dummy)	-0.513	-0.204	-0.813	-0.864	-0.813	-2.568**
	(0.672)	(0.553)	(0.551)	(0.537)	(0.543)	(1.211)
Legal Structure (Dummy)	-	-	0.932	1.163*	0.932*	2.614**
	-	-	(0.635)	(0.646)	(0.519)	(1.260)
Year (Trend)	-2.438**	-2.174**	-1.542*	-1.778**	-1.542*	4.737*
	(1.186)	(0.982)	(0.884)	(0.798)	(0.884)	(2.727)
Year_Squared (Trend)	0.198	0.150	0.107	0.130	0.107	-1.036**
	(0.153)	(0.128)	(0.114)	(0.102)	(0.126)	(0.484)
N	126	126	208	208	208	208
Number of Firms in Sample	42	42	64	64	64	

Standard errors in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%

The significant results from the smaller sample are robust and appear in the larger dataset in the last two columns of Table 2. In other results, public firms appear to be marginally more likely to acquire CMM certification as compared with private firms. Additionally, firms with larger capital bases appear to be marginally less likely to acquire CMM certification. It is possible that firms with larger capital bases possibly face lesser pressure to gain cost efficiencies through process initiatives. We also see some indications of larger and older firms being more prone to acquire CMM certification in our analysis, though these results are not statistically significant. In summary, our results are consistent with the signaling argument for why firms would acquire CMM certification in markets characterized by information asymmetry between clients and vendors.

We now turn to the effects of CMM certification on the firm's performance. Table 3 shows the results from the OLS, fixed effects and random effects estimation for the average cost equation. Both the fixed effects and random effects estimation show that CMM certification leads to a reduction in average costs. It is worth noting that the trend term *Year* is negative, indicating that the Indian industry as a whole appears to be trending downwards with respect to average cost, but at a decreasing rate as seen by the *Year_Squared* coefficient. Even after accounting for this yearly trend, CMM certification is associated with a reduction in average cost. However, the magnitude of the effect is small (FE = -0.073, RE = -0.043) when compared to the sample statistics (mean=0.846, sd=0.17). Given that low-cost firms are more likely to acquire certification, it appears that on average, certified firms may not experience very large cost efficiencies. Other results in this estimation show that older firms have lower average costs, as expected from Banerjee and Duflo (2000). Additionally, larger firms have lower average costs, indicating economies of scales with respect to costs.

Table 3: Effect of Certification on Average Cost

	OLS	**Fixed Effects**	**Random Effects**
Constant	1.273***	1.768***	1.379***
	(0.157)	(0.322)	(0.217)
CMM Level (Lagged)	-0.012	-0.073**	-0.043**
	(0.033)	(0.028)	(0.02)
Firm Size (Employees)	-0.010	-0.112**	-0.048*
	(0.018)	(0.048)	(0.028)
Subscribed Capital	-0.032**	0.038**	0.019
	(0.015)	(0.015)	(0.013)
Age (Years)	-0.035	-0.102***	-0.082**
	(0.027)	(0.029)	(0.036)
Location (Dummy)	0.054*		0.053
	(0.030)		(0.049)
Ownership (Dummy)	0.049		0.010
	(0.030)		(0.032)
Year (Trend)	-0.130*	-0.083**	-0.094**
	(0.067)	(0.039)	(0.040)
Year_Squared (Trend)	0.019**	0.015***	0.015***
	(0.008)	(0.005)	(0.005)
N	169	169	169
Number of firms	43	43	43
R-squared	0.14	0.26	

Huber-White Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

The results of certification on the firm's demand side show interesting results, as seen in Tables 4. As in the previous case, the first 3 columns show the results with average cost as an independent variable. The CMM variable is highly significant and positive on its effect on exports from the firm, and this effect is seen in the OLS, fixed effects as well as the random effects models, indicating support for Hypothesis 4. The last three columns show the results from the larger sample when we drop the average cost variable; the results with respect to CMM certification are broadly consistent. A significant finding is the magnitude of the effect that certification appears to have on the firm's exports. The most conservative estimate of the effect is the fixed effects coefficient (beta=0.235), which translates into an increased revenue of roughly Rupees 1.25M, all else being equal. This could either result from increased revenues on existing services / products or higher margins (prices) on services / products with demonstrably higher quality. It is not possible in our dataset to distinguish between these two cases; however, the impact of certification on the firm's demand side is significant and consistent with prior theory in signaling.

Table 4: Effect of Certification on Exports

	OLS	FE	RE	OLS	FE	RE
Constant	-0.127	-0.354	-1.105	-2.738**	-1.616	-3.022***
	(1.569)	(1.658)	(1.130)	(1.306)	(0.988)	(0.988)
CMM Level (Lagged)	0.652***	0.235*	0.319**	0.625***	0.368**	0.408**
	(0.165)	(0.128)	(0.141)	(0.163)	(0.169)	(0.187)
Average Cost	0.096	-0.036	-0.023			
	(0.399)	(0.496)	(0.498)			
Service-specific Competition	-13.282	-6.454	-6.884	-0.136	2.189	0.210
	(8.730)	(6.202)	(5.641)	(1.877)	(5.504)	(0.941)
Competitor CMM	-1.323	-1.560	-1.260	-0.086	-1.324	-1.010
	(2.510)	(1.327)	(1.224)	(2.059)	(1.174)	(1.378)
Firm Size (Employees)	0.829***	0.873***	0.925***	0.983***	0.896***	1.042***
	(0.095)	(0.245)	(0.112)	(0.091)	(0.197)	(0.111)
Subscribed Capital	0.100	-0.034	0.003	0.010	0.005	0.058
	(0.079)	(0.110)	(0.076)	(0.063)	(0.059)	(0.060)
Age (Years)	0.446***	0.438***	0.489***	0.316**	0.487***	0.434**
	(0.134)	(0.160)	(0.144)	(0.123)	(0.174)	(0.192)
Location (Dummy)	0.107		0.203	0.350**		0.522***
	(0.154)		(0.208)	(0.148)		(0.201)
Ownership (Dummy)	0.213		0.025	0.322**		0.234
	(0.154)		(0.121)	(0.145)		(0.226)
Legal Structure (Dummy)				-0.242		-0.054
				(0.179)		(0.215)
Year (Trend)	-0.169	0.206	0.191	0.602	0.462**	0.426
	(0.506)	(0.283)	(0.272)	(0.447)	(0.227)	(0.366)
Year_Squared (Trend)	0.047	0.012	0.005	-0.054	-0.024	-0.020
	(0.090)	(0.048)	(0.048)	(0.078)	(0.040)	(0.060)
N	165	165	165	257	257	257
Number of firms	42	42	42	65	65	65
R-squared	0.71	0.64		0.65	0.66	

Huber-White Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Test for Endogeneity – the Heckman two stage procedure

As discussed before, endogeneity arising from an omitted variable could possibly bias the coefficients in the average cost and exports models described above. As suggested in the literature, we use the cross-sectional Heckman procedure on the year 2000 data to check for the effects of endogeneity. We operationalize the Heckman procedure as follows. We use the independent variables from 1999 as instruments for the CMM certification decision in 1999. The probit model is evaluated for the 1999 decision to acquire certification, and the Inverse Mills Ratios are calculated from the 1999 sub-sample[6]. The Inverse Mills Ratios are then introduced into the 2000 performance equations along with the lagged CMM variable and estimated as the second part of the Heckman two-stage procedure. We have data on 57 firms in 2000 and the results from the estimated average cost and exports equations

[6] We use the probit as opposed to the logit model here since the Heckman procedure requires the probit specification. The results from both specifications are identical in our context.

are shown in Table 5[7]. We also perform the same analysis for the 2001 and 2002 cross-sections with consistent results across all three years.

The instruments we use to capture the CMM certification decision in the first stage are adequate for two reasons. First, the probit model for CMM certification includes variables that are not present in both the average cost and exports equations. Thus, we are not relying on the functional form of the probit model alone to provide identification but are able to meet the identification conditions required by including variables in the probit model that are not present in the subsequent performance equations. Second, by using data from 1999 in estimating the probability of CMM certification, we are able to prevent any simultaneity between the instruments in 1999 and the performance measured at the end of 2000; that is, the instruments we use are theoretically orthogonal to the performance variables in 2000. While firms may still have expectations of future performance which may result in some residual correlation between the instruments and the dependent variable, there is little reason to postulate direct correlations between the instruments measured in 1999 and performance measured at the end of 2000.

The results from the Heckman two-stage procedure, shown in Table 6, indicate that even in the year 2000 cross-section, the effect of the lagged CMM certification is significant on exports. However, the effects of certification on average cost are insignificant; this result could be driven by the small sample (N=38) for which these data are available in 2000. The Inverse Mills Ratio is significant in the exports equation, indicating that in this particular case, there might be some bias arising from an omitted variable. The other results are broadly consistent with the panel data analysis discussed earlier.

Table 5: Results from the Heckman Two-Stage Method for 2000 Cross-section
Effect of CMM Certification on Average Cost and Exports

Dependent Variable	**Average Cost**	**Exports**
Constant	1.150	-1.791
	(0.241)	(2.442)
CMM Level (Lagged)	0.084	1.526***
	(0.121)	(0.521)
Service-specific Competition		-60.111**
		(31.56)
Competitor CMM		7.571
		(6.532)
Firm Size (Employees)	-0.042	0.730***
	(-0.040)	(0.176)
Subscribed Capital	0.002	0.035
	(0.027)	(0.11)
Age (Years)	-0.064	0.451**
	(-0.055)	(0.24)
Location (Dummy)	0.062	0.185
	(-0.059)	(0.283)
Ownership (Dummy)	0.092	-0.049
	(0.061)	(-0.286)
Legal Structure (Dummy)		0.027
		(0.299)
Lambda (Inverse Mills Ratio)	-0.058	-0.780**
	(-0.077)	(0.328)
Observations	38	57
R-squared	0.14	0.69
* significant at 10%; ** significant at 5%; *** significant at 1%		

[7] Since endogeneity only biases the coefficients of the performance equations and not the certification decision model, in the interest of space, we only provide the second-stage performance estimates.

Further Explorations of the Effects of CMM Certification

In the above specification, we measure CMM as a status variable (0 before the certification and 1 after the certification) in equation (3); this variable therefore reflects the average impact of CMM certification on exports post-certification. It does not provide insights into whether CMM certification has a short-term or a long-term effect on exports. Examining this question not only allows a better understanding of how CMM influences exports, it can be viewed as a further test of the signaling argument because it suggests that CMM certification's impact will be strongest immediately after the firm gains the signal. Once the signal has been acquired, the firm may not continue to experience exports growth at an abnormal rate beyond a point unless the firm's structural characteristics change.

We transform equation (3) by first-differencing all the variables as shown below:

$$\Delta Exports_{it} = f\,(\Delta CMM_{i,t-1}, \Delta Competition_{it}, \Delta Competitor\_CMM_{it}, \Delta Size_{it}, \Delta Year\text{-}Squared_{t}) + \varepsilon_{it} \qquad (4)$$

Note that time-invariant variables like age, year, location, ownership, and legal structure are dropped due to the first-differencing method. The key benefit in the above specification is that the $\Delta CMM_{i,t}$ variable now captures only the impact of the signal when it is issued. Once the firm is certified, ΔCMM_{it} returns to 0 for the remainder of the panel, unlike CMM_{it} which remains 1 after certification. By varying the lag of $\Delta CMM_{i,t}$ term, we are able to examine how the impacts of CMM on exports change over time. The results for the one-year and two-year lagged terms ($\Delta CMM_{i,t-1}$ and $\Delta CMM_{i,t-2}$) are reported in Table 6, Columns 1 and 2. Essentially, this part of the analysis allows us to answer the question: is there an increase in the growth of exports one or two years after the firm acquires CMM certification, or is the exports growth only a one-time event?

Table 6: First Differences model on CMM's Impacts on Exports

	One-year lag	Two-year lag
CMM (Lagged)	0.295*	0.053
	(0.158)	(0.150)
Service-specific Competition	-2.514	-0.560
	(4.649)	(5.894)
Competitor CMM	0.686	0.992
	(0.761)	(0.953)
Firm Size (Employees)	0.527***	0.417**
	(0.150)	(0.178)
Subscribed Capital	-0.056	-0.041
	(0.052)	(0.072)
Year_Squared (Trend)	-0.068**	-0.081**
	(0.026)	(0.032)
Constant	0.735***	0.878***
	(0.179)	(0.245)
N	172	120
R-squared	0.10	0.09
Robust standard errors in parenthesesLambda		
* significant at 10%; ** significant at 5%; *** significant at 1%		

We find that the results of the one-year lag ($\Delta CMM_{i,t-1}$) are quite similar to those of the fixed-effects model (Column 2 in Table 4). The impact of CMM on next year's exports is both positive and significant. When we lag $\Delta CMM_{i,t}$ for another year (Column 2 in Table 6), however, the coefficient of ΔCMM becomes insignificant. In further lags, the ΔCMM remains insignificant (not reported in Table 6). The above results indicate that the impact of

CMM certification on exports occurs mainly in the first year following certification. This suggests that the role of CMM certification has only a short-term impact on exports.

In summary, our analysis of the effects of CMM certification clearly indicates demand-side benefits; exports show a significant improvement from certification, all else being equal. Our results also show that firms experience some supply-side benefits as well; the firm's average operating cost decreases after a firm's certification. However, the magnitude of the reduction in average cost appears small and disappears after controlling for endogeneity. The signaling argument for why certification would provide benefits to firms that operate in markets with information asymmetry appears to hold true in the Indian offshore IT industry—firms that are able to generate the CMM signal are able to distinguish themselves from other firms and gain significant demand-side benefits.

Our results also complement prior literature that has evaluated the benefits of process certification at the project level. Harter et al (2000) and Krishnan et al (2000) show that processes positively impact project-level performance indicators such as cycle times and productivity. Our results show that these efficiencies aggregate somewhat at the level of the firm as well. However, little existing work on CMM adoption has shown the cost of adopting CMM or, indeed, the accruing benefits from the firm's demand side. Our analysis shows that the major business value from CMM adoption appears to come from increased exports, all else being equal. Therefore, even in the case of no significant improvement in internal efficiencies, firms appear to benefit with respect to their demand side when they acquire CMM certification.

It is possible that increased exports come from higher margins on existing sales through improved quality, that is, the immediate impact of CMM certification is higher quality and not necessarily higher revenues or exports (Herbsleb et al 1997). In our analysis, it is not possible to control for quality since CMM certification is often used as a proxy for quality. In other words, high quality and CMM certification are co-determined. It is precisely this inability to ex ante evaluate quality from a potential vendor that creates value in the signal.

Conclusion

Our objective in this paper was to study the determinants of and the subsequent effects, if any, of acquiring CMM certification in the Indian offshore exports industry. Our results from the certification choice model reflect the signaling rationale (Spence 1973; Anderson et al 1999), wherein more cost-efficient companies tend to invest in generating the signal. In addition, firms that operate in export markets, where the institutional environment encourages certification as a means to reducing information asymmetry, are also more likely to acquire certification. CMM certification is also associated with strong demand-side effects, characterized by significant lagged effects of CMM on total exports of the firm. In addition, we do not find significant evidence for the effect of CMM certification on the firm's average cost of operations.

The analysis we present in this paper is subject to certain limitations. First, our sampling structure focuses on the larger and more prominent companies in the Indian offshore market, with implications for the generalizability of the results. The concentrated nature of the Indian offshore industry necessitates such a sampling approach. Our sample is highly representative of the Indian industry from an exports market size viewpoint. Generalizing our results on the basis of other factors such as firm size or vertical segments has to be done with caution. Second, it is possible that the effects of certification lead to higher output quality, which indirectly leads to higher export revenues. To the extent that certification and quality improvement are co-determined, more research is needed to tease out the separate effects on firm performance.

Our work also points to future avenues of research. First, we only study the one-time effect of CMM certification on firm performance. It is possible, as has been proposed by the SEI (Paulk et al 1993), that process certification leads to continued improvement in a firm's performance. This would imply that certification enhances the firm's growth rate in a dynamic manner. Testing this would require longer panels of data since these effects would appear over longer periods of lags. Second, it can be argued that process certification can substitute for hiring trained personnel, that is, it is possible for a firm to hire inexperienced personnel but use a rigorous process to ensure high quality services. This would provide firms in tight labor markets with reasonable means of justifying investments in process initiatives. Finally, institutional theory postulates that the reasons for early adoption of process initiatives could be based on normative beliefs about the value of processes while later adopters are more influenced by institutional pressures than expectations of efficiencies. It would be interesting to test whether early adopters of third-party certification significantly differ from late adopters in terms of the efficiency gains they experience.

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