In recent years, there has been increasing pressure on the US federal government to reduce spending and improve the management of its technology projects. Mitigating the adverse impact of risks on the performance of these projects presents a significant challenge for its stakeholders. Our research examines this challenge in two steps. First, we identify and define a set of salient risks in federal technology projects—specifically, complexity risk and contracting risk in the planning process, and execution risk in the execution process. Next, we investigate whether higher levels of process maturity, assessed by the Capability Maturity Model Integration (CMMI) framework, mitigate the negative effect of project risks on project performance. The analysis of time-series data collected from 82 federal technology projects across 519 quarterly time periods indicates that each of the three types of risks has a significant negative effect on project performance. This finding highlights the practical significance of managing these risks in the federal technology project context. Further, we find that increasing levels of process maturity attenuate the negative effect of project risks on the performance of federal technology projects. However, the attenuation effects are consequential only at high levels of project risks; at low levels of project risk, increasing levels of process maturity can adversely affect project performance. To demonstrate the financial implications of increasing process maturity levels in federal technology projects, we examine the magnitude of project cost savings (and overruns) across different levels of CMMI and project risks. In summary, our study contributes to the sparse literature on public sector operations by addressing the understudied context of federal technology projects, and provides a nuanced examination of the implications of process maturity in managing the risk to performance relationship in such projects.

Key words: Project Management; Process Maturity; Project Risk; Federal Technology Projects; Public Sector

1. Introduction

“To assist agencies in managing their investments, Congress enacted the Clinger-Cohen Act of 1996, which requires OMB (Office of Management and Budget) to establish processes to analyze, track, and evaluate the risks and results of major capital investments in information systems made by federal agencies and report to Congress on the net program performance benefits achieved as a result of these investments (US Government Accountability Office Report 2010, p. 3).”

“As the Obama administration steps up oversight of high-risk IT projects, contracting organizations must take greater responsibility to provide a level of confidence in the services they offer. That is where one of the latest offerings from the Software Engineering Institute at Carnegie Mellon University can help (Sacks 2010).”

US federal government technology initiatives are frequently organized and executed in the form of technology projects (Kundra 2010, Weigelt 2010). Examples of federal technology projects include information infrastructure development (e.g., the recent Health Insurance Marketplace or Obamacare implementation) for the Department of Health and Human Services, application development (e.g., navigation systems in missiles and unmanned vehicles) for the Department of Defense, and web-based supply chain management system for the Department of Agriculture. Recent data tracked by the OMB indicate that the occurrence of schedule and cost overruns in federal technology projects is widespread with considerable financial implications—nearly 25% of such projects with a cumulative total budget exceeding $10 billion and spread over 28 government agencies are facing moderate to severe problems in meeting their schedule and budgetary targets (Source: www.itdashboard.gov). Additionally, the US Government Accountability Office Report (2010) indicates that approximately 72% of federal technology projects amounting to a total budget of $27 billion are deemed to be poorly planned with the likelihood of encoun-
tering significant schedule and cost overruns (see Table 1).

Despite this evidence of schedule and budget overruns in federal technology projects, the challenges associated with the effective management of such projects, and more generally, of projects in the public sector domain, have received scant attention in the extant operations management (OM) literature (Venkatesh et al. 2012, Verma et al. 2005). Much of our understanding of project management has been drawn from studies focusing on the private sector (e.g., Boyne 2002, Chapman and Ward 2003). A review of the literature on public sector administration indicates that technology projects in this sector differ from their counterparts in the private sector in a number of ways. These include a greater emphasis on governmental regulations (Bozeman and Kingsley 1998), increased complexity arising from sizeable resource requirements and technological uncertainty (Dillon et al. 2002, Ferratt et al. 2006), and the involvement of multiple stakeholders with disparate and sometimes conflicting goals (Metcalfe 1993), in public sector projects. These attributes of public sector technology projects, coupled with their focus on maximizing public utility instead of maximizing profits (Ferlie et al. 1996), results in escalating commitment where organizational resources funded by taxpayers’ money continue to get absorbed in the project without concomitant progress.

Given the notable differences between public and private sector technology projects, skepticism about the applicability of “private sector models” in the public administration domain (Fottler 1981, Boyne 2002), and the scarcity of research on project management in the public sector, an empirical investigation of challenges in federal technology projects presents a fruitful area of research for OM scholars. Further, in the current economic scenario, mounting pressure on the federal government to reduce costs and growing calls in political and media circles for the efficient utilization of taxpayer contributions (Kane 2011, Colvin 2012) underscores the practical relevance of research examining the management of federal technology projects. Toward this end, our study has two major objectives.

First, we identify a set of salient risks in federal technology projects (Gefen et al. 2008, Keil et al. 1998). Focusing on planning and execution processes within a federal technology project, we identify three distinct types of project risk—namely, complexity risk and contracting risk that primarily arise in the planning process and execution risk that is prevalent in the execution process. Complexity risk increases with the level of technological uncertainty and scope associated with the project. For example, the development of an altitude control system for a surface-to-air missile, which includes a sub-component on the missile and a sub-component on the ground, is likely to involve greater levels of complexity risk compared to the development of the individual sub-components itself. Contracting risk, on the other hand, is the risk associated with the selection of appropriate contractors and the coordination of interdependent project tasks and processes in the contracting relationship. As the number of contractors and the extent of work carried out by contractors in a federal technology project increases, the contracting risk in the project increases. Finally, execution risk refers to disruptions in project progress that may arise from several factors including changes in project requirements, inadequate resources, lack of federal government involvement, and differences among its various stakeholders. For example, the Health Insurance Marketplace project was widely reported to have high levels of contracting risk (due to a significant number of interdependencies across multiple contractors) and execution risk (due to changing requirements during project execution), all of which resulted in significant implementation challenges downstream (Bellovin 2013, Thibodeau 2013). As per industry standards² and legislations passed by the federal government (e.g., the Clinger-Cohen Act of 1996; see Appendix A, Table A1), the performance of federal technology projects is reported to OMB on a quarterly basis using earned value metrics on schedule and cost performance. We, therefore, use a composite earned value metric, that is,

### Table 1 Percentage of Federal Technology Projects over Fiscal Years 2004–2009 with Potential Schedule and Budget Overruns (as Denoted by Projects on Management Watch List)

<table>
<thead>
<tr>
<th>Fiscal year</th>
<th>Number of major federal technology projects</th>
<th>Associated budget ($ in billions)</th>
<th>Number of management watch list projects</th>
<th>Associated budget ($ in billions)</th>
<th>% of federal technology projects on management watch list</th>
<th>% of budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>1400</td>
<td>$59.0</td>
<td>771</td>
<td>$20.9</td>
<td>55</td>
<td>35</td>
</tr>
<tr>
<td>2005</td>
<td>1200</td>
<td>60.0</td>
<td>621</td>
<td>22.0</td>
<td>52</td>
<td>37</td>
</tr>
<tr>
<td>2006</td>
<td>1087</td>
<td>65.0</td>
<td>342</td>
<td>15.0</td>
<td>31</td>
<td>23</td>
</tr>
<tr>
<td>2007</td>
<td>857</td>
<td>64.0</td>
<td>263</td>
<td>9.9</td>
<td>31</td>
<td>15</td>
</tr>
<tr>
<td>2008</td>
<td>840</td>
<td>65.0</td>
<td>346</td>
<td>14.0</td>
<td>41</td>
<td>22</td>
</tr>
<tr>
<td>2009</td>
<td>810</td>
<td>70.7</td>
<td>585</td>
<td>27.0</td>
<td>72</td>
<td>38</td>
</tr>
</tbody>
</table>

schedule-cost performance index (SCPI) to examine the performance impact of these risks. Second, prior research has emphasized the need for mature and formal project processes as they lead to improvements in the control and predictability of project outcomes (e.g., Patnayakuni et al. 2007, Slaughter et al. 2006). In the context of federal technology projects, the vendor’s capability to reliably deliver mission-critical technology solutions (i.e., the vendor’s use of mature processes within a project) is assessed using the Capability Maturity Model Integration (CMMI) framework developed by the Software Engineering Institute (SEI). The framework consists of five levels (levels 1–5) which represent the evolution of an organization’s processes from immature and informal to mature and formal, and define the related infrastructure necessary to support these processes at an organizational level (Harter et al. 2012). As a signal of process excellence, CMMI level 3 represents a significant step toward process maturity (Gopal and Gao 2009). Unlike projects in the private sector, contractors and vendors are often required to possess CMMI certification in order to bid for federal government technology projects (Hilden and Hilden 2008), and CMMI level 3 certification is frequently used as a key qualifying criterion for awarding federal contracts (Thibodeau 2013, Warner 2012). Given the considerable commitment of time and organizational resources required to obtain CMMI certification (Gopal and Gao 2009), it is important to investigate whether higher levels of process maturity—i.e., CMMI level 3 and higher—are beneficial in mitigating the effect of project risks on performance in federal technology projects.

Our empirical analysis is conducted using time-series panel data collected across 519 quarterly time periods from 82 federal technology projects carried out by Lockheed Martin, a Fortune 100 global technology firm that specializes in the development of large aerospace, defense, and security systems for the federal government (i.e., the client organization). The time-series nature of the data derives from the fact that metrics for each project in the study’s sample are tracked by the firm and reported to the OMB on a quarterly basis. The results provide empirical support for the arguments that each of the three types of risks—complexity, contracting, and execution risks—reduce a project’s ability to meet its cost and schedule targets. Further, our results underscore the effect of higher CMMI levels in attenuating the negative effects of project risks on performance in federal technology projects. More importantly, they indicate that the attenuating effect of CMMI on the risk–performance relationship is stronger only at high risk levels; at lower risk levels, projects with high maturity levels (e.g., levels 4 and 5) perform poorly on schedule and cost metrics compared to projects with low (e.g., level 3) maturity levels. To demonstrate the financial impact of increasing process maturity levels in federal technology projects, we conduct post hoc analysis to examine the magnitude of savings (and overruns) in project costs across different levels of CMMI and project risks. In summary, our study’s findings contribute to the literature on the management of public sector operations by addressing the understudied context of federal technology projects, and provide a nuanced understanding of the implications of process maturity in managing the risk to performance relationship in these projects.

The study is organized as follows. In section 2, we review the extant literature on process maturity models and technology project risks, and identify gaps in these literature streams that require greater attention. Section 3 provides the conceptual foundation for our research, wherein we derive a set of hypotheses examining the interrelationships between project risks, process maturity levels, and project performance. In section 4, we describe the data collection procedure and sample characteristics; while in section 5 we present our model specification, analysis, and results. Finally, in section 6, we discuss the study’s contributions and limitations, and suggest directions for future research.

2. Theoretical Background

2.1. The CMMI Process Maturity Framework

CMMI represents a widely used framework in the federal government for assessing and improving the maturity of product or systems development processes across a project, division, or an entire organization (Chriissis et al. 2011, CMMI for Development 2010). A process is said to be mature when it is “explicitly defined, managed, measured, controlled, and effective” (Paulk et al. 1993, p. 5). The maturity of a process is assessed in the CMMI framework by five levels (see Figure 1).

Each level represents a progressive step toward achieving mature processes with level 1 representing processes that are ad hoc and chaotic and level 5 representing highly mature and disciplined processes. The transition from level 1 through to level 5 is a systematic procedure that involves the institutionalization of disciplined processes in several “process areas.” These process areas lead to structured work routines that can be utilized as a learning platform, paving the way for knowledge-driven performance improvement in technology projects (Ramasubbu et al. 2008). Significant investments of organizational resources and improvements in processes are required in order to be certified at level 3; an organization can continue to make progress and achieve certification at levels 4
and 5, by formalizing additional organizational processes, as well as by improving the processes previously implemented at level 3 (Eickelmann 2003).

With increasing adoption of the CMMI framework in practice, a number of studies have examined the benefits of process maturity in the private sector. For example, studies at the organizational level (e.g., Gopal and Gao 2009) show that higher levels of process maturity provide a signal of organizational process competency for vendor firms and influence their performance. However, much of the existing literature is based on the earlier CMM framework, with a focus on lower process maturity levels (levels 1–3), and primarily examines their implications for software development outcomes such as software quality, effort, etc., (Harter and Slaughter 2003, Harter et al. 2000). Table 2 summarizes some of the salient literature focusing on the relationship of process maturity levels with software development outcomes. As evident from Table 2, with the exception of the Harter et al. (2012) study (which examines CMM levels 1–5 and focuses solely on software quality outcomes), research on higher process maturity levels (i.e., levels 4 and 5) is sparse, and their performance implications remain largely understudied. Given that certification at higher process maturity levels involves significant investment of organizational time and resources, their implications for project outcomes, as well as their interactions with project level factors, requires greater attention in research and practice (Harter and Slaughter 2003). Further, as noted earlier, in recent years, the federal government has begun to place significant emphasis on higher process maturity levels using the newer CMMI framework (Hilden and Hilden 2008), typically employing CMMI level 3 as a qualifying criterion for vendors to bid for its technology projects. How do higher process maturity levels affect a vendor firm’s ability to mitigate the adverse effects of project risks in federal technology projects? This remains an open empirical research question.

This research endeavors to address the question posed above in the process maturity-project risk management context. First, departing from prior studies which have examined the performance implications of lower process maturity levels (i.e., levels 1–3 as assessed by the older CMM framework) primarily on software development metrics, we focus on understanding the implications of higher process maturity levels (i.e., levels 4 and 5 as assessed by the newer CMMI framework) for project performance—namely project schedule and budget performance. Second, and more importantly, unlike prior studies which have examined the direct effects of process maturity levels on project performance, we examine its moderating effects on the relationship between project risk and project performance. Finally, we complement extant studies on process maturity that have primarily focused on software system development in the private sector, by studying technology projects in the public sector. Specifically, we focus on US federal government technology projects whose activities incorporate both information systems development as well as integration (of software, hardware, new information technologies, support, etc.). In sum, the focus of our study on higher process maturity levels in the context of federal technology projects has significant economic implications for the federal government and its contractors. Findings from this study can

![Figure 1 Process Maturity Levels in CMMI Framework.](source: CMMI for Development, 2010.)
guide stakeholders in the evaluation and efficient allocation of taxpayer resources in technology projects, which can result in significant savings.

In the following paragraphs, we review the extant literature on project risks in technology projects and identify a set of key risks relevant to the context of federal technology projects.

2.2. Risk Identification and Management in Technology Projects

The study of risk factors in technology projects, their implications for project performance, and potential ways to manage their adverse performance implications has a rich tradition in the extant decision theory and microeconomics literature (e.g., Arrow 1965, MacCrimmon and Wehrung 1986, March and Shapira 1987). The decision theory perspective examines the risk of a decision alternative in terms of variation in possible outcomes, in their likelihoods, and in their subjective values (Arrow 1965). This viewpoint implicitly considers a decision maker to be passive in managing risk, assumes that all alternatives are given, and cannot be subsequently adjusted. In contrast, the behavioral view associates risk with both the probability and magnitude of an undesirable outcome (March and Shapira 1987); therefore controlling risk requires proactive efforts by managers in understanding the environment and negotiating contracts that reduce uncertainty (MacCrimmon and Wehrung 1986).5

Consistent with the behavioral view, current project management practice considers risk identification and management to be an important role of the project manager. Yet a review of the extant literature indicates a focus on technology project risks that are often beyond the direct control of the project manager and project team—that is, risks that are largely driven by the organizational and external environments. For example, in a Delphi study, Keil et al. (1998) found that managers’ perceptions of risks in technology projects were skewed toward factors that were often external to the project environment. Realizing the need for a greater focus on identification and management of “internal” project-level risks inherent in technology projects, they identify two such sets of project-level risks: (i) scope and requirements risks—i.e., risks pertaining to project scope and requirements in the planning process, and (ii) execution risks—i.e., risks pertaining to project execution factors such as insufficient staffing, improper allocation of roles and responsibilities, absence of systematic development and testing procedures, etc. The above representation of key project-level risks that are under the control of the project team has also been supported in a subsequent multi-country Delphi study by Schmidt et al. (2001). Consistent with the above studies, Wallace et al. (2004) identify two major categories of risk that are under the influence of the project team: (i) technical subsystem risk that arises from uncertainty in requirements and project complexity, and (ii) project management risk that arises due to ineffective control and team issues such as team turnover, insufficient knowledge, etc. Finally, building on this literature, Barki et al. (2001) develop a contingency framework for managing risks in technology projects. Their core

Table 2: Summary of Key Studies on Process Maturity Levels

<table>
<thead>
<tr>
<th>Study</th>
<th>Research question</th>
<th>CMM/CMMI levels</th>
<th>Key dependent variable(s)</th>
<th>Selected independent variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harter et al. (2000)</td>
<td>Examines the role of process maturity on quality, cycle time and effort in software development</td>
<td>CMM levels 1–3</td>
<td>Quality, effort, and cycle time</td>
<td>CMM levels 1–3</td>
</tr>
<tr>
<td>Harter and Slaughter (2003)</td>
<td>Effect of quality improvement on infrastructure activity costs in software development</td>
<td>CMM levels 1–3</td>
<td>Product quality and infrastructure activity costs</td>
<td>Product quality and CMM levels 1–3</td>
</tr>
<tr>
<td>Gopal and Gao (2009)</td>
<td>Examine firms’ motivation to obtain CMM certification (Level 3 and above) and its subsequent impact on firm performance</td>
<td>CMM level 3, and sensitivity analysis for higher CMM levels</td>
<td>CMM certification (level 3 and above) Leading values of firm exports and firm average costs</td>
<td>CMM certification (level 3 or above), Lagged values of firm exports and firm average costs</td>
</tr>
<tr>
<td>Harter et al. (2012)</td>
<td>Examines the role of software process maturity in reducing severity of defects</td>
<td>CMM levels 1–5</td>
<td>Quality (high severity defects)</td>
<td>Direct effects: Size, complexity, requirements ambiguity, and CMM levels 1–5</td>
</tr>
<tr>
<td>This study</td>
<td>Examines the effect of three types of project risks on project performance, and the role of higher CMMI levels as a risk mitigation mechanism</td>
<td>CMMI levels 3–5</td>
<td>Schedule-cost performance index (earned value metric)</td>
<td>Direct effects: complexity risk, contracting risk, and execution risk Moderating effect: CMMI levels 3–5</td>
</tr>
</tbody>
</table>
argument is that project performance is driven by the degree of fit between project risks and the processes used to manage them. Besides the studies identified above, much of the technology project risk literature has its origins in the software engineering literature (e.g., Boehm 1991) where efforts at risk identification have largely focused on creation of risk “checklists” based on interviews with managers. Such checklists form a starting point for identifying project risks, but have limited theoretical background and do not provide a systematic classification approach for future studies to adapt and extend.

Our review of the project risk management literature further indicates that, with a few exceptions (e.g., Wallace et al. 2004), there is limited empirical research that uses large-scale data and rigorous econometric approaches to examine the performance implications of project risks and the efficacies of risk mitigation approaches. The literature on risk management in public sector technology projects is even sparser (Boyne 2002, Dillon et al. 2002). Yet, as documented from a number of surveys and reports in popular press (Foxton 2014, Goldfinch 2007, McKinsey 2012), public sector technology projects involve considerable investment of taxpayer resources and face considerable risks during their planning and execution stages, an area that remains understudied. Our study addresses the above gaps in the technology project risk management literature. First, we focus on the understudied context of risks in public sector technology projects, specifically, technology projects implemented by the federal government. The federal government represents the single largest industry setting in the United States in terms of its investment in technology projects, with an annual outlay exceeding 75 billion dollars in the last 5 years. Given the magnitude of investments, research focusing on the effective management of risks in these projects has significant potential to generate savings, while ensuring that the public utility from federal government projects continues to be maximized. Second, we build upon risk identification models in the extant literature (e.g., Keil et al. 1998, Wallace et al. 2004), and practitioner studies on public sector technology projects (e.g., Dillon et al. 2002, McKinsey 2012) to identify project risks, and conduct a rigorous empirical investigation of their performance implications in the context of federal technology projects. Specifically, we map risks across planning and execution processes in federal technology projects, and focus on the following risk factors—complexity risk and contracting risk which arise primarily during the planning process, and execution risk which arises during the execution process (as shown in Figure 2). Next, we discuss each of these risks in greater detail and examine the underlying mechanisms through which they affect project performance in each period.

3. Hypotheses Development

3.1. Risks and Performance in Federal Technology Projects

3.1.1. Complexity Risk. Federal technology projects often involve the implementation of organization-wide initiatives that are knowledge-intensive and require team members to comprehend and assimilate diverse technical knowledge related to their project’s tasks. As these tasks are often interdependent, accomplishing them necessitates extensive coordination among project team members (Clark and Fujimoto 1991, Gerwin and Barrowman 2002). To that end, and consistent with prior studies (e.g., Barki et al. 2001, Novak and Eppinger 2001, Xia and Lee 2005), we define complexity risk in a federal technology project as risks arising from: (i) technological uncertainties in performing the project’s tasks; and (ii) the interdependent nature of tasks associated with the project. Technological uncertainty is the extent to which project team members are knowledgeable (or not) about the technological requirements of their tasks (Pavlou and Savvy 2006, Tatikonda and Rosenthal 2000). Task interdependence, on the other hand, arises from the architecture of the systems under development, and affects the intensity, flow, and direction of knowledge transfer between team members (Hoegl et al. 2004).

Research on task characteristics has shown that, with increasing levels of complexity risk in federal technology projects, team members are often subjected to greater levels of dual-task-processing—a cognitive activity that occurs when an individual attempts to concurrently perform two distinct activities (Langfred and Moye 2004). One activity relates to the use of tech-
technical knowledge or problem-solving skills to perform a specific project task and is particularly salient when technological uncertainty of the task is high. While individuals and team members performing such tasks will need to spend time and resources in searching for knowledge and brainstorming solutions, it also necessitates greater communication within and outside the team with frequent requests for clarification (Novak and Eppinger 2001). The other activity relates to the levels of task interdependence in a project and requires team members to ensure that knowledge inputs associated with tasks, as well as their interface specifications, are taken into account when performing them. As task interdependence increases, changes in one task may influence other tasks, and conflicting elements of interrelated tasks may have to be resolved for the overall system to function correctly (Espinosa et al. 2007, Hoegl et al. 2004). Dual-task processing often leads to loss of efficiency and lower performance (Levy and Pashler 2001), as the bounded rationality of team members limits their ability to effectively allocate cognitive resources for performing multiple tasks (Rubinstein et al. 2001). Further, the lack of effective coordination between team members handling technologically uncertain and/or interdependent tasks can cause significant rework in project tasks and result in schedule and budget overruns in the project. In summary, increasing levels of complexity risk would lead to a decrease in performance in federal technology projects.

**HYPOTHESIS 1A.** Complexity risk is negatively associated with performance in federal technology projects in each quarter.

**3.1.2. Contracting Risk.** Given the diverse and specialized nature of technical knowledge required in federal technology projects, organizations often attempt to alleviate knowledge resource constraints and lower costs by entering into contracting relationships (Li et al. 2012, Mayer and Nickerson 2005). While contracting presents significant benefits, it can also be a source of project risk. The underlying basis for contracting risk is the effect of adverse selection and moral hazard problems that arise in a contracting context (Bolton and Dewatripont 2005). Adverse selection problems arise when an organization selects an inappropriate contractor—that is, when a contractor does not have the required skills and technical capabilities (Gefen et al. 2008). Moral hazard problems, on the other hand, are associated with the need to deal with unsatisfactory contractor effort after the contract has been signed (Snir and Hitt 2004). Based on the above discussion, contracting risk in federal technology projects is defined as the risk associated with the selection of unsuitable contractors, and the coordination of interdependent project tasks and processes between the organization and its contractors. Such risks are exacerbated with increase in (i) the number of distinct contractors; and (ii) the proportion of contracted work in a project (Metcalfe 1993).

Specifically, as the number of distinct contractors increases, the organization is more likely to encounter adverse selection and moral hazard problems, as it faces greater challenges in selecting suitable contractors, monitoring individual contracting relationships, and ensuring effective contractual safeguards (Li et al. 2012). Similarly, as the proportion of contracted work in a project increases, contractors will be responsible for a greater portion of the total effort in a project, which will heighten the impact of adverse selection and moral hazard problems. Further, as the organization and its contractors are likely to differ in their areas of expertise and hold unique “private” knowledge (business domain knowledge vs. technical knowledge) (Tiwana 2008), this increases the possibility that each side may fail to transfer critical task related knowledge. As the proportion of contracted work and the number of distinct contractors in a project increases, the problem of knowledge transfer is amplified, resulting in delays and inefficiencies when contractors perform their tasks. Based on these arguments, we hypothesize:

**HYPOTHESIS 1B.** Contracting risk is negatively associated with performance in federal technology projects in each quarter.

**3.1.3. Execution Risk.** Execution risk refers to disruptions in the progress of a project due to unforeseen situations or uncertainties during its execution (Loch et al. 2006, Wallace and Keil 2004). Federal technology projects are often subject to considerable risks during project execution that may arise from a multitude of factors including changes in project requirements, inadequate availability of resources, lack of federal government involvement, and differences in development methodologies across its various stakeholders (Mayer and Nickerson 2005, Sakthivel 2007). Existing studies often assume that the planning process presents a dominant source of risks for managers and that the risks that arise in the project execution process are generally less severe on project outcomes (Keil et al. 1998). In practice, this is not always true; for example, Wallace and Keil (2004, p. 73) argue that “managers chiefly concerned with meeting deadlines and budget limitations must find ways to reduce the risk associated with project execution,” as these risks have a greater impact in shaping project outcomes.

A key challenge in identifying execution risks within a project arises from the fact that such risks typically develop during the course of a project’s...
execution and are, therefore, unknown or unac-
counted for during the project planning process. 
Given that project execution risks are often unex-
pected, addressing such risks can require significant 
managerial attention as well as coordination among 
project personnel, detracting from task execution and 
leading to inefficient use of project resources. Often 
project managers resort to costly “firefighting” and 
redirect project resources from ongoing tasks to man-
age risk, which in turn hinders the overall execution 
of the project and affects project performance.

HYPOTHESIS 1c. Execution risk is negatively associated 
with performance in federal technology projects in each 
quarter.

Having hypothesized the direct effects of project 
risks on performance in federal technology projects, 
we now develop a theoretical framework, wherein we 
examine the interrelationships between project risks, 
process maturity levels, and project performance.

3.2. Moderating Effects of CMMI on Project Risks-
Project Performance Relationship

In considering the effect of CMMI on the relation-
ship between project risks and performance, we 
characterize CMMI as a knowledge-based process 
 improvement approach. Knowledge is an important 
organizational resource that can be tacit, scarce, and 
difficult to transfer or replicate (Grant 1996). Organi-
zational processes use knowledge to enable produc-
tive activities to be performed. To obtain coherence 
and predictability, such knowledge needs to be 
articulated, codified, and shared within the organiz-
ation. When existing knowledge, especially tacit 
knowledge, embedded in organizational processes is 
codified, the resulting processes are not only detailed 
and specific with predictable outcomes, but also sus-
tainable in the long run (Helfat 1997, Nelson and 
Winter 1982). Codification of organizational knowl-
edge may involve specifying policies, and procedures 
based on prior experience or instituting templates and 
standards that represent industry-wide best prac-
tices (Becker et al. 2005).

In the context of federal technology projects, the 
CMMI process maturity framework facilitates the 
codification of tacit organizational knowledge 
through a continuous cycle of contextualization—
wherein processes are tailored and interpreted at the 
project and functional group level—and institutional-
ization—wherein the effects noticed at the project level 
are generalized and applied at the organizational 
level (Raelin 1997, Ramasubbu et al. 2008). The 
contextualization–institutionalization cycle enhances 
an organization’s ability in using knowledge to 
respond to risks and manage its consequences. There-
fore, instead of intuitive, ad hoc approaches for mana-
ging the risk-performance relationship in federal 
technology projects, using a formal approach enables 
proactive management of such a relationship through 
the use of systematic processes for identifying, assess-
ing, and prioritizing risks. Since codification of orga-
nizational knowledge aids organizations in managing 
the effect of risks on performance, CMMI encourages 
development of formal processes through the institu-
tionalization of a process area, namely, Risk Manage-
ment, at level 3 (CMMI for Development 2010). The 
purpose of this process area is “to identify potential 
problems before they occur so that risk handling 
activities can be planned and invoked as needed 
across the life of the product or project to mitigate 
adverse impacts on achieving objectives” (CMMI for 
Development 2010, p. 349), indicating that CMMI has 
the potential to attenuate the negative project risk to 
performance relationships hypothesized in H1a, H1b, 
and H1c. In addition, a number of process areas at dif-
ferent CMMI levels, may contribute to mitigating the 
adverse effects of risk on project performance. Since 
an organization at a higher CMMI level also imple-
ments the process areas required for a lower CMMI 
level, therefore the effect of these process areas is 
cumulative with increasing process maturity.  

While the above discussion provides an overarch-
ing theoretical foundation for the role of the CMMI 
process maturity framework in managing the rela-
tionship between project risks and project perfor-
ance, we provide theoretical arguments and 
develop hypotheses for the moderating role of CMMI 
on the relationship between each of the three project 
risks—complexity risk, contracting risk, and execu-
tion risk—and project performance.

Specifically, while complexity risk can diminish 
project performance, such effects are often exacer-
bated in the absence of formal processes for coordina-
tion across team members (Choo et al. 2007, Kirsch 
et al. 2002). Further, Holmqvist (2004) notes that in 
the absence of formal processes, team members are 
more likely to “get stuck” in brainstorming ideas and 
problem-solving techniques without making suffi-
cient progress on task completion. Greater individual 
discretion in task completion can create inconsistency 
in coordination and consequently diminish knowl-
edge transfer, leading to weaker performance. 
Therefore, as complexity risk increases, stronger 
monitoring is needed to facilitate coordination in 
order to improve performance (Mayer and Nickerson 
2005). Such monitoring can be achieved by imple-
menting CMMI which not only mandates specific 
procedures for coordination and knowledge transfer, 
but also establishes thresholds for deviations in task 
performance that allow team members to verify if the 
task has been accomplished correctly (CMMI for
Development 2010, Krishnan et al. 2000). This reduces team members’ ambiguity about their respective individual actions and establishes accountability in areas requiring joint action (Kirsch et al. 2002). In addition, implementation of CMMI requires formal processes to ensure that important cost and schedule information (i.e., knowledge) relating to individual tasks be regularly shared and disseminated among project team members during task execution, helping team members to make appropriate performance tradeoffs (e.g., between cost and schedule). Establishing a set of formal procedures as per CMMI process area guidelines, can reduce the negative effect of complexity risk on the overall time and cost needed for project completion. In addition, process areas at higher CMMI levels will further attenuate this negative relationship. Hence, we posit the following hypothesis:

**Hypothesis 2A.** Higher levels of process maturity will attenuate the negative association between complexity risk and performance in federal technology projects in each quarter.

A key step in reducing contracting risk’s negative relationship with project performance involves coordinating contractors’ efforts—with the organization and with each other—to ensure both effective knowledge transfer as well as consistency in problem solving across interdependent tasks performed by the organization and its contractors (Lavie et al. 2007, Li et al. 2012). In this respect, CMMI provides the necessary structure for improving coordination and enhancing the transaction value in an organization’s contracting relationships. First, it provides formal guidelines for knowledge exchange between the organization and its contractors, and for integrating their contributions in a project. For example, a key prescription from CMMI involves using peer discussions for integrating tasks, in place of individualistic (and sometimes ad hoc) decision making (Paulk 1995), which “minimize heterogeneity of the interpretation of information and aid in consensus building” (Ramasubbu et al. 2008, p. 441). It facilitates codification of knowledge gained from peer discussions, which is then subsequently utilized in reducing the negative effects of contracting risk on project performance. Second, CMMI infuses order into contracting relationships by ensuring consistency of task procedures, technical standards, and performance evaluation criteria between an organization and its contractors, thereby minimizing contextual differences among contracting parties and helping them make better use of their resources to maximize project performance (CMMI for Development 2010, Kirsch et al. 2002). Finally, CMMI minimizes the negative performance effects of adverse selection by providing a systematic screening mechanism to organizations for selecting contractors (CMMI for Development 2010). Such a mechanism ensures that only contractors that have the expertise and competencies necessary for executing the project are selected. Higher CMMI levels institutionalize additional practices that enhance this outcome. The above arguments highlight the role of CMMI in mitigating the adverse performance consequences of contracting risks in federal technology projects.

**Hypothesis 2B.** Higher levels of process maturity will attenuate the negative association between contracting risk and performance in federal technology projects in each quarter.

Finally, we argue that the negative effect of execution risks on federal technology project performance are attenuated with increasing maturity levels. Specifically, the CMMI framework requires detailed documentation of historical risk events and activities that have created process variance and influenced project performance during project execution. Projects are mandated to track and collect data from reactive (incident-based processes) as well as proactive (audit/assessment-based processes) events (Chrissis et al. 2011, CMMI for Development 2010). Further, managerial actions that were effective for improving performance during earlier risk events are documented in a knowledge base. These activities provide a rich shared context—that is, the project manager and team members have access to the same information, share the same tools, work processes, and work cultures (Chapman and Ward 2003, Hinds and Mortensen 2005). Rather than relying solely on managerial capabilities for addressing project execution risks, implementing CMMI enables the project manager and team members to draw useful problem solving knowledge not only from the project’s historical database, but also from the organization’s experience in ensuring project performance in the presence of execution risks. CMMI thus provides a platform for knowledge-driven performance improvement which helps improve the implementation of project execution processes. Further, process areas related to higher CMMI levels progressively establish a set of routines and procedures for addressing different types of problems that originate from poor execution, which can reduce the overall time and cost needed for project completion. Therefore, we posit that CMMI enables the execution of project processes to be accomplished on a routine, structured and predictable basis, which mitigates the adverse effect of execution risk on the performance of federal technology projects; with higher CMMI levels enhancing the mitigation effect. Therefore, we hypothesize the following:
Hypothesis 2c. Higher levels of process maturity will attenuate the negative association between execution risk and performance in federal technology projects in each quarter.

4. Research Design

4.1. Data Collection

To test our hypotheses, we obtained secondary, archival data from Lockheed Martin, a Fortune 100 global high technology firm. As of 2012, Lockheed Martin has more than 500 facilities in the United States and has widespread global presence in 75 countries worldwide. The company specializes in the development and delivery of large aerospace, defense and security systems. The major portion of its business is with U.S. federal government agencies (e.g., Department of Defense); the remainder of its business is comprised of international government sales and commercial sales to industry. The company’s operations are organized in four focused areas: Aeronautics, Electronic Systems, Information Systems, and Space Systems, each with multiple divisions. For our study, we obtained data on federal technology projects conducted by different divisions within the Information Systems area.

The data used in this study is tracked on a quarterly basis by the Information Systems area as part of its Operations Excellence program. The program maintains a repository of current and archival data on all projects and activities initiated within the firm, using a rigorous two-step data collection procedure. In the first step, tactical and project specific details are collected on a monthly basis as part of the monthly review process within the Information Systems area. The review process is typically conducted by a panel consisting of vice presidents, project managers, and deputy project managers within the area. In the second step, the monthly data is aggregated to form quarterly status reports that are used for a strategic review and evaluation of project performance. In addition, these reports are used for internal auditing purposes and to create lessons learned. The monthly review process and aggregation of data to quarterly levels is consistent with the recommendations of the ANSI/EIA-748 Earned Value Management Standard—that is widely used by federal contractors. To ensure accuracy in data collection, the operational excellence unit triangulates the data through multiple sources (e.g., interviews with project managers and senior managers within the area, and project documents). The projects evaluated in this study are drawn from a proprietary database of federal technology projects that were completed during the period 2002–2012, by the divisions in the Information Systems area. This led to an initial sample of 93 projects with data across 548 quarterly time periods. Missing data across 11 projects reduced the sample size to 82 projects with data across 519 quarterly time periods for conducting the analysis.

With respect to project characteristics in a given quarter, the median project team size is 40 members (in full-time equivalents, FTE’s) with a median budget of $35 million. The median % of the project budget that is allocated to labor costs is 70%, with the remaining 30% allocated to project material and infrastructure costs. The median number of quarters per project is five, and the work allocated to be performed by sub-contractors is 20%; with the median number of sub-contractors being two.

4.2. Dependent and Independent Variables

4.2.1. Project Performance. The performance of federal technology projects is monitored by Lockheed Martin through earned value management (EVM) metrics, notably the Schedule Performance Index (SPI) and the Cost Performance Index (CPI). EVM is a project planning and control approach which compares actual accomplishment of scheduled work and associated costs against an integrated schedule and budget plan, on a periodic basis (Fleming and Koppelman 2005, Goh and Hall 2013). As per industry standards and federal legislation (e.g., the Clinger-Cohen Act of 1996, see Table A1 in Appendix A), the use of EVM for monitoring the performance of federal technology projects has been mandated by the OMB. Consequently, contractors implementing federal technology projects diligently implement EVM as part of their project management processes. In addition, EVM is increasingly being regarded in the private sector as a project management “best practice,” and has been adopted by many companies in the non-governmental sector that want to improve project planning, visibility, and control (Meredith and Mantel 2009). The periodic collection of data on earned value accomplished, and comparison of the associated cost with the planned value of the project, allows organizations to continuously monitor and evaluate project progress, better predict its cost at completion, and use earned value metrics as milestones for making contractual payments. Any updates or revisions to the planned value of the project also result in a concomitant adjustment of the earned value in a given time-period. EVM, thus, provides a consistent evaluation of project performance unlike traditional metrics for schedule or budget overruns.

Both SPI and CPI are widely used ratio indicators of schedule and cost performance of a project (see Appendix A, Table A2, for details on measurement of SPI and CPI), where values equal to, greater than, or less than 100%, respectively, indicate project performance matching, exceeding, or not achieving planned progress (Fleming and Koppelman 2005). We obtain values for SPI and CPI for each project-quarter pair in
our data. Given the similarity in their descriptive statistics and the high correlation between these measures ($\rho = 0.68$, $p < 0.01$), we use their average to create a composite performance metric, Schedule-Cost Performance Index (SCPI), for the dependent variable in our analysis. Composite metrics of schedule and cost performance have been widely used in prior literature (Faraj and Sproull 2000, Gerwin and Barrowman 2002). From a practical viewpoint, the underlying logic for combining the two metrics is that delays in project schedule often lead to increases in project costs as project managers generally rely on crashing techniques to improve schedule performance (Meredith and Mantel 2009).

### 4.2.2. Process Maturity.

The CMMI framework is used to evaluate the maturity of an organization’s processes. Since level 3 represents a significant step in achieving process excellence, has risk management as a key process area, and incorporates the qualifying criteria used frequently by the federal government to award project contracts (Warner 2012), the federal technology projects in our study’s sample have maturity levels that span levels 3–5. Specifically, among the 82 projects in our sample, 26 projects were implemented at level 3, 25 projects were implemented at level 4, and the remaining 31 projects were implemented at level 5. Although the data is collected from projects within a single organization, the variation in CMMI levels across projects is observed for several reasons. First, the projects have been implemented in different divisions within the Information Systems area in Lockheed Martin; these divisions may be certified at different CMMI levels. Second, as CMMI is “nested,” (i.e., level 5 includes all process areas up to level 4, plus two additional process areas, and so on), an organization certified at level 5, can elect to perform a certain project at level 4, by implementing process areas that are required up to Level 4, and not implementing process areas that are only required in level 5. More importantly, the choice of which CMMI level to implement for a project is made by the organization after extensive consultation with the customer (a federal government entity). Finally, though the CMMI level for any individual project does not vary with time, the different projects in our sample were initiated at different points in time in the 2002–2012 time frame; therefore, the different CMMI levels for projects in the same division reflect the progression in a division’s process maturity over time.

Using CMMI 3 as the base category, we create two dummy variables, CMMI 4 and CMMI 5, to represent the three maturity levels in our analysis.

### 4.2.3. Complexity Risk.

Complexity risk in federal technology projects is measured by Lockheed Martin across two dimensions: technological uncertainty and project scope. Each of these two dimensions are measured by the firm on a five-point Likert scale—i.e., for technological uncertainty, 1 = Low, 3 = Medium, 5 = High; for project scope, 1 = Assembly, 3 = System, 5 = Array (similar to Shenhar 2001). The terms, Assembly, System, and Array are therefore used as anchors in a 5-point scale, with a project classified as an “assembly” if it involves the development of major subcomponent (e.g., development of a fiber-optic motion sensor for a surface-to-air missile), a “system” if it involves the development of a collection of subcomponents (e.g., development of an altitude control system for a surface-to-air missile which includes a sub-component on the missile and a sub-component on the ground), and an “array” if it involves the development of a large number of systems that integrate together to form a cohesive whole (e.g., the guidance system of a surface-to-air missile). We created a composite measure of complexity risk by averaging the values of technological uncertainty and project scope for each project.

### 4.2.4. Contracting Risk.

Contracting risk in federal technology projects is measured by Lockheed Martin across two dimensions: (i) sub-contracting percentage—that is, the % of project execution work that is sub-contracted by the organization, and (ii) the number of distinct sub-contractors that are used in a project. Given the differences in the measurement scales across these two dimensions, we created a composite measure of contracting risk using factor weights derived from principal components analysis of these two dimensions (Hair 2006). Increasing values of this composite measure represent increasing levels of contracting risk.

### 4.2.5. Execution Risk.

The extent of execution risk in a federal technology project is tracked by Lockheed Martin using a count of the number of risk factors on the project’s risk register. A risk register is a formal document that lists the key risk factors in a project along with their potential impact and the planned response to addressing the risk factors (Meredith and Mantel 2009). Risk factors identified in the register are likely to arise during the execution of a project’s tasks and influence its continued progress. For example, execution risk factors may include inadequate availability of resources and lack of client involvement in project execution, and differences in development methodologies across the various stakeholders (e.g., federal government and contractors). The greater the count of execution risk factors for a project, the greater is its level of execution risk.

While the above three risks are likely to co-vary in each quarter, they represent three distinct types of
risks. In addition, the highest pairwise correlation among the three risks is fairly low at 0.33, indicating that the risks are distinct from each other.

4.3. Control Variables
External factors pertaining to project characteristics could be a source of heterogeneity both within and across projects, and contribute to observed differences in project performance. We therefore controlled for several such characteristics, as discussed below, in our analysis.

- **Project Budget** \(_{it}\) – denotes the budgetary allocation (in millions of dollars) for project \(i\) in quarter \(t\).
- **Project Size** \(_{it}\) – denotes the number of employees (in full-time equivalent) for project \(i\) in quarter \(t\).
- **Project Labor** \(_{it}\) – denotes the % of the budget for project \(i\) in quarter \(t\), dedicated to labor costs.
- **Project Priority** \(_{it}\) – denotes a binary variable which is coded as “1” if project \(i\) in quarter \(t\) had a high priority and “0” otherwise.
- **Prime** – denotes a binary variable which is coded as “1” if the firm is the prime contractor for project \(i\) and “0” otherwise.
- **Federal Government Review** \(_{it}\) – denotes a binary variable which is coded as “1” if a formal federal government review occurred for project \(i\) in quarter \(t\) and “0” otherwise.
- **Federal Government Perception** \(_{it}\) – denotes a binary variable which is coded as “1” if the federal government perceived project \(i\) in quarter \(t\) to be risky and “0” otherwise. From the federal government’s standpoint, greater perception of risk within a project in a given quarter is likely to influence the extent to which they are engaged in the project and interact with the project team.
- **Change Order** \(_{it}\) – denotes a binary variable which is coded as “1” if a significant change order was received for project \(i\) in quarter \(t\) and “0” otherwise. Change orders were not considered a risk since only 5% of the project-quarter pairs had change orders.

Table 3 provides the summary statistics and the pairwise correlations for all the variables in the analysis.

5. Analysis and Results

5.1. Model Specification
As discussed earlier, the data in our sample is structured as time series panel data with observations from 82 projects across 519 quarterly time periods. This requires an estimation approach that corrects for autocorrelation and heteroskedasticity (Greene 2003, Kennedy 2008). Autocorrelation is likely to arise in the data due to correlation between values of the dependent variable (SCPI) in current and previous time periods and the extent of autocorrelation may vary across projects. Heteroskedasticity may arise from unobserved heterogeneity or omitted variables across projects. Each issue can generate biased estimates. While both fixed and random effects models account for the panel structure of the data, they do not account for cross-sectional correlation or heteroskedastic error structures across panels (Greene 2003). We therefore use the generalized least squares (GLS) regression method that corrects for both panel-specific autocorrelation and heteroskedasticity to analyze the data (xtgls command in Stata 11). The regression model for testing the hypotheses is shown below. For project \(i\) and time period \(t\):

\[
SCPI_{it} = \beta_0 + \beta_1 \cdot ProjectBudget_{it} + \beta_2 \cdot ProjectSize_{it} + \beta_3 \cdot ProjectLabor_{it} + \\
\quad + \beta_4 \cdot ProjectPriority_{it} + \beta_5 \cdot Prime_{it} + \beta_6 \cdot FederalGovernmentReview_{it} + \\
\quad + \beta_7 \cdot FederalGovernmentPerception_{it} + \beta_8 \cdot ChangeOrder_{it} + \\
\quad + \beta_9 \cdot ComplexityRisk_{it} + \beta_{10} \cdot ContractingRisk_{it} + \beta_{11} \cdot ExecutionRisk_{it} + \\
\quad + \beta_{12} \cdot CMMI4_{it} + \beta_{13} \cdot CMMI5_{it} + \\
\quad + \beta_{14} \cdot ComplexityRisk_{it} \times CMMI4_{it} + \beta_{15} \cdot ComplexityRisk_{it} \times CMMI5_{it} + \\
\quad + \beta_{16} \cdot ContractingRisk_{it} \times CMMI4_{it} + \beta_{17} \cdot ContractingRisk_{it} \times CMMI5_{it} + \\
\quad + \beta_{18} \cdot ExecutionRisk_{it} \times CMMI4_{it} + \beta_{19} \cdot ExecutionRisk_{it} \times CMMI5_{it} + u_{it}.
\]

Further, the first-order autocorrelated error term, \(u_{it}\), in the above model is given by the equation,

\[
u_{it} = \rho \cdot u_{i(t-1)} + e_{it}.
\] (2)

In the above equation \(\rho\) represents the autocorrelation coefficient that is estimated using Durbin-Watson
method and $e_t$ represents the normally distributed error term with mean zero and variance $\sigma_e^2$.

### 5.2. Hypotheses Tests

The estimation results for equation (1) are shown in Table 4 in a hierarchical manner. Model 1 presents the results from the base model which includes only control variables, followed by addition of the independent variables in Model 2, and the interaction variables in Model 3. To mitigate multicollinearity concerns, we standardize the risk variables before creating the interaction terms (Kutner et al. 2005). The highest VIF value for Model 3 is well below the suggested cutoff values of 10 and the average VIF is < 3 suggesting that multicollinearity is not an issue in the analysis (Kennedy 2008). The overall chi-square for each model indicates significant explanatory power.

To test our hypotheses, we examine the coefficients of the variables in Model 3. The analysis results for this model indicate that complexity risk ($\beta = -4.203$, $p < 0.01$) and execution risk ($\beta = -4.453$, $p < 0.01$), each have a significant negative impact on SCPI, thereby providing support for Hypotheses 1a and 1c, respectively. However, the negative effect of contracting risk on SCPI is weaker ($\beta = -1.625$, $p < 0.10$), providing limited support for Hypothesis 1b. Taken together, these results support our fundamental premise that each of these three variables captures a distinct source of risk that has detrimental consequences on the schedule and cost performance of a project.

Hypothesis 2a posits that increasing levels of process maturity attenuate the negative relationship between complexity risk and SCPI. The analysis results in Model 3 indicate a positive moderation effect of CMMI 4 ($\beta = 4.358$, $p < 0.01$) and CMMI 5 ($\beta = 3.660$, $p < 0.01$) on the relationship between complexity risk and SCPI. Hypothesis 2a is therefore supported in our analysis. To better understand this moderating effect, we examine a conditional effects plot (Aiken and West 1991). Figure 3 represent the conditional effects plots for the relationship between SCPI and CMMI across different levels (high – one standard deviation above the mean, and low – one standard deviation below the mean) of complexity risk (Kutner et al. 2005). Consistent with our hypothesis, the conditional effects plot for complexity risk highlight a clear negative association between this risk and SCPI in federal technology projects at CMMI 3 which diminishes at higher levels of process maturity (i.e., CMMI 4 and CMMI 5).

Hypothesis 2b posits that increasing levels of process maturity attenuate the negative relationship between contracting risk and SCPI. The analysis results in Model 3 indicate a positive moderation of CMMI 4 ($\beta = 8.414$, $p < 0.01$) and CMMI 5 ($\beta = 2.813$,
p < 0.05) on the relationship between contracting risk and SCPI. Hypothesis 2b is therefore supported in our analysis. A closer look at the conditional effects plot in Figure 4 below reveals that while contracting risk has a significant negative association with SCPI at CMMI 3, this negative association weakens at CMMI 4 and CMMI 5.

Hypothesis 2c posits that increasing levels of process maturity attenuate the negative relationship between execution risk and SCPI. The analysis results in Model 3 indicate the positive moderation effect of CMMI 5 (β = 2.695, p < 0.05) on the relationship between execution risk and SCPI. However, we do not observe a significant moderation effect for CMMI 4. Hypothesis 3b is therefore partially supported in our analysis. The conditional effects plot in Figure 5 provides support for the above findings and highlight the marginal benefits of CMMI 5 on the relationship between execution risk and SCPI.

5.3. Robustness Checks

We conduct additional analyses to check the robustness of our results to alternate model specifications and to exclude alternative explanations. First, we re-specify the dependent variable in a number of ways: (i) using individual measures of CPI and SPI; and (ii) using a product of SPI and CPI. Second, we check the sensitivity of our results to alternative methods for computing autocorrelation using: (i) adjusted Durbin-Watson method and (ii) time-series autocorrelation of residuals (Greene 2003). Third, we consider the possibility that there may be potential interactions

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<th>Table 4 Generalized Least Squares (GLS) Regression Results: Corrected for Panel Specific AR (1) Autocorrelation and Heteroskedastic Errors</th>
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* p < 0.1, ** p < 0.05, *** p < 0.01; standard errors are reported in the parentheses.
between the various risk factors in our study, and conduct a robustness check by including interactions between the risk factors (Complexity Risk \times Contracting Risk, Complexity Risk \times Execution Risk, and Contracting Risk \times Execution Risk) in the analysis. Estimations using each of the above alternative specifications of the model are consistent with our primary results.

Fourth, we consider the possibility that process maturity variables may be endogenous in our analysis. Such a possibility is less likely to influence our results for three reasons. First, macro-level variables that have been shown to influence the selection of maturity level (e.g., institutional pressures, legitimacy requirements in industry) (Gopal and Gao 2009) are less likely to influence the performance outcomes at the project level. Second, should such omitted variables influence the performance at the project level, their effects are likely to be partially reflected in correlated errors across projects. To that end, our analysis corrects for panel-specific autocorrelation. Third, the maturity level remains invariant throughout a project’s duration whereas project performance values can vary across each quarter of the project. As such, reverse causality is unlikely to be an issue. Nonetheless, to check for endogeneity of process maturity variables, we conduct the two-stage Durbin-Wu-Hausman’s test (Maddala 2001). In the first stage, we estimate an OLS regression model with process maturity level as the dependent variable. While the OLS regression may not represent the correct functional form for a categorical dependent variable, such an approach, nonetheless, generates consistent estimates (Angrist and Krueger 2001). In addition to control variables and project risk variables, we include the following instrumental variables: (i) year of project initiation – a categorical variable representing the year of project initiation (2002–2011), and (ii) duration of the project – in terms of the number of quarters over which the project is accomplished. These variables are more likely to influence the maturity level for a project and are theoretically not related directly with project performance. For example, projects initiated in earlier years are more likely to involve lower process maturity levels compared to those implemented recently. Further, projects of longer duration involve a greater commitment of human and technical resources, and are more likely to be perceived by the federal government as prone to risks in the planning and execution processes.

In addition to intuitive support for the choice of instrumental variables, econometricians have become more reliant on robust statistical evidence to assess instrumental variable relevance and exogeneity (French and Popovici 2011). The property of instrument relevance can be established by evaluating the strength of the instrument’s effects on the endogenous regressor. In our case, the Anderson canonical correlation Lagrange Multiplier (LM) test for instrument relevance is highly significant ($\chi^2 = 89.83$, df = 11, $p < 0.01$), highlighting their strong predictive power in the first stage model. To test for the property of instrument exogeneity, we carried out a Sargan-Hansen test for overidentification (Davidson and MacKinnon 2004). A failure to reject the null hypothesis provides statistical support in favor of the exogeneity assumption of the instrument. In our analysis, the Sargan-Hansen test is statistically insignificant ($\chi^2 = 14.63$, df = 10, $p > 0.10$), indicating that the instrumental variables chosen are less likely to be correlated with the error term in the second-stage model. Taken together, the above results provide support for the empirical validity of the instruments in the study.

Following the estimation of the first stage model predicting process maturity, the residual variable $ResCMM$ from this model is used as an input into the second stage model predicting project performance, as shown in equation (1). This variable is not statistically significant ($\chi^2 = 2.41$, df = 1, $p > 0.10$) indicating...
that endogeneity of process maturity level is less likely to be a concern in our analysis (see Table A3 in Appendix A). Finally, to exclude alternative explanations that may arise from influential observations and potential outliers in our data, we utilize two measures: (i) the leverage statistic, \( h \); and (ii) the Cook’s distance statistic, \( D \). The leverage statistic, \( h \), assesses how far a value of the independent variable is from the mean value; with more distant observations having greater leverage. The value of \( h \) ranges from 0 (no influence on the model) to 1 (completely determines the model). A rule of thumb is that cases with \( h < 0.2 \) are not a problem, while those with \( h > 0.5 \) should be examined for the possibility of measurement error or analyzed separately. The Cook’s distance measure, \( D \), represents an alternative way of measuring the leverage, and captures the effect of deleting a case on the analysis. If there is a significant change in the results, the deleted case would represent an influential case. As a general rule of thumb, values of \( D > 4/n \) represent influential cases in the analysis. The values of the leverage statistic, \( h \), are well below the cutoff values of 0.5 with values ranging between 0.011 and 0.235, indicating the absence of influential observations in our analysis. The Cook’s distance statistic, \( D \), has values ranging from 0.000 to 0.046 in our analysis. We identify 38 (of the 523) observations in our data that are deemed as influential based on the cutoff value of \( D = 0.008 \) (i.e., \( 4/n = 4/523 = 0.008 \)). These influential observations are deleted and the analysis is conducted on the reduced sample.11 The results from this revised analysis are consistent with those obtained in the main analysis, highlighting the robustness of our results to influential observations.

5.4. Comparison of Moderation Effects Across CMMI 4 and CMMI 5

The moderation hypotheses in this study examine whether higher levels of process maturity (i.e., CMMI 4 and 5) reduce the negative effects of project risks on project performance relative to CMMI 3. However, this does not provide information about the differences in moderating effects between CMMI 4 and 5. To investigate these differences, we exclude projects that are at CMMI 3, and conduct our analysis on projects at CMMI 4 and 5 only \((n = 60, \text{ periods } = 366)\). Using a dummy variable with CMMI 4 as the comparison group, we examine the incremental moderating effects of CMMI 5 on the relationship between each of the three project risks and project performance. The results indicate that the interaction term of CMMI 5 with contracting risk is negative and significant \((\beta = -4.790, \ p < 0.05)\) whereas that with execution risk is positive and significant \((\beta = 4.120, \ p < 0.01)\). In contrast, similar analysis conducted on projects at CMMI 3 and 4 only \((n = 50, \text{ periods } = 331)\) indicate significant positive interactions between CMMI 4 with complexity risk \((\beta = 4.995, \ p < 0.01)\), and contracting risk \((\beta = 8.103, \ p < 0.01)\). Taken together, the above analyses indicate that while higher process maturity levels moderate the negative relationship between project risks on project performance, their effects are asymmetric; that is, CMMI 4 is significantly beneficial in mitigating the adverse effect of risks that arise during the planning process. The incremental benefit of progressing from CMMI 4 to CMMI 5 is that the latter mitigates the effect of risks that arise during the execution process.

5.5. Economic Significance of the Role of CMMI on Project Performance

To illustrate the economic significance of process maturity in mitigating the effect of risks in federal technology projects, we examine the implications of CMMI levels 3, 4 and 5 under varying levels of project risks on the estimated cost of completion (EAC) of the project. This analysis is conducted in three steps. In the first step, we estimate the dependent variable (SCPI) at low (−1 SD, −2 SD), average, and high (+1 SD, +2 SD) levels of project risks across different process maturity levels, holding all control variable values at their means. Next, based on a median project budget of $35 million in the sample, we determine EAC using the formula (Meredith and Mantel 2009): \( EAC = (\text{Project Budget} / \text{SCPI}) \times 100 \).12 Finally, for a given risk level, we examine the differences in EAC values across different maturity levels to determine potential savings in project budget.

The analysis results, shown in Table 5, highlight the potential cost savings that may result for executing projects at higher maturity levels when project risk levels are high. Specifically, given a project budget of $35 million (based on the median project budget value in our sample), executing the project at CMMI 4 or CMMI 5 when project risks are high is associated with potential savings of $5.19 million and $2.95 million, respectively, compared to executing the project at CMMI 3. In contrast, when project risk levels are low, executing the project at CMMI 4 or CMMI 5 is associated with potential cost overruns amounting to $4.55 million and $4.63 million, respectively, compared to executing the project at CMMI 3.

These theoretical calculations provide valuable insights about the economic significance of the interaction between project risks and process maturity levels. However, appropriate caution should be exercised in interpreting the magnitude of cost savings as the economic impact of the joint effects of project risks and process maturity levels may vary across organizations. Nonetheless, from a project risk management perspective, the above findings indicate that higher
process maturity levels are not always beneficial, and the benefits from executing a project at high levels of process maturity are observed only when projects risks are high. At low levels of risk, high process maturity levels can lead to significant cost overruns for the project. We surmise that higher levels of process maturity can create significant transactional burden on the project as they require project stakeholders to extensively document and track project activities, invest in training, conduct audits, etc. (CMMI for Development 2010). At low levels of risk, the performance benefits arising from increasing levels of process maturity may not be sufficiently high to outweigh the significant cost of resources allocated for ensuring compliance with high CMMI levels, thereby diminishing project performance. This represents an important finding as it highlights potential drawbacks of higher process maturity levels.

6. Discussion

6.1. Summary of Findings and Theoretical Contributions

With significant pressure on the federal government to trim spending and become fiscally conservative (Hoover 2012, Kane 2011), federal technology projects are being closely monitored by government agencies and vendor firms are facing increasing pressures to reduce schedule and cost overruns. Hence, in the current economic scenario, the importance of identifying project risks and managing their effect on project performance cannot be overstated. Our study has two major objectives. The first objective is to conceptualize and measure key risks in federal technology projects. Consistent with the extant project risk literature (e.g., Keil et al. 1998, Wallace et al. 2004), we identify and map risks associated with specific project processes. We focus on project planning and execution processes, and identify three distinct types of risks—complexity risk, contracting risk and execution risk. Such a framework is particularly useful for both theory and practice as it draws attention toward risks that are not widely addressed in the literature, namely, contracting and execution risks (Wallace et al. 2004). To assess their effects on project performance, we use a composite metric of schedule and budget performance, that is, schedule-cost performance index (SCPI). The results indicate that complexity risk and execution risk have a significant negative effect on SCPI, while the negative effect of contracting risk on SCPI is much weaker.

The second objective of this study is to examine the role of CMMI (a process maturity framework), in mitigating the performance impact of project risks. Results indicate that increasing levels of process maturity attenuates the negative effect of project risks on schedule and cost performance. The above findings make the following contributions to research and practice.

First, our study focuses on an important and largely understudied area of research in the OM literature—the management of public sector operations (Venkatesh et al. 2012, Verma et al. 2005), and particularly, the context of federal technology projects (Dillon et al. 2002). As reported earlier in Table 1, the federal government expenditures for technology projects have exceeded $60 billion each year since fiscal year 2005, with planned expenditure of nearly $78 billion for technology projects in fiscal year 2015 (Source: www.itdashboard.gov). Given the level of financial resources at stake, it is critical that federal technology projects be planned and managed effectively to ensure that taxpayer contributions are spent wisely. Yet, research focusing on federal technology projects, and more broadly, on public sector projects is practically non-existent. Our study addresses this important gap in the literature.

The second contribution lies in developing a nuanced understanding of the mode by which process maturity influences project performance. This is important to both theory and practice given the significant investment of resources and time that is required to acquire CMMI certification. Most studies in the extant literature are based on the earlier CMM framework, focusing primarily on maturity levels 1–3, and have examined the direct effect of CMM levels on

<table>
<thead>
<tr>
<th>Program risk levels (Mean ± 1 SD, Mean ± 2 SD)</th>
<th>CMMI level 3</th>
<th>CMMI level 4</th>
<th>CMMI level 5</th>
<th>ΔSCPI CMMI level 4 – CMMI level 3</th>
<th>ΔSCPI CMMI level 5 – CMMI level 3</th>
<th>Cost variance* [CMMI level 3 – CMMI level 4]</th>
<th>Cost variance* [CMMI level 3 – CMMI level 5]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>–1.00</td>
<td>102.58</td>
<td>90.52</td>
<td>90.33</td>
<td>–12.06</td>
<td>–12.25</td>
<td>$4.55 million</td>
</tr>
<tr>
<td>Average</td>
<td>–2.00</td>
<td>112.86</td>
<td>89.09</td>
<td>91.44</td>
<td>–23.77</td>
<td>–21.42</td>
<td>$8.27 million</td>
</tr>
<tr>
<td>High</td>
<td>0.00</td>
<td>92.30</td>
<td>91.95</td>
<td>89.22</td>
<td>–0.35</td>
<td>–3.08</td>
<td>$0.14 million</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>82.02</td>
<td>93.38</td>
<td>88.11</td>
<td>11.36</td>
<td>6.09</td>
<td>$5.19 million</td>
</tr>
<tr>
<td></td>
<td>2.00</td>
<td>71.74</td>
<td>94.81</td>
<td>87.00</td>
<td>23.07</td>
<td>15.26</td>
<td>$11.87 million</td>
</tr>
</tbody>
</table>

*ΔEAC values calculated using median project budget value ($35 million).
software development metrics such as development effort, product quality, etc. Our study focuses on higher maturity levels within the newer CMMI framework, and goes beyond an assessment of the direct effects of higher CMMI levels on project performance by investigating their moderating effects in the context of project risks. Specifically, our research focuses on project performance in terms of schedule-cost performance (SCPI) and explicates the role of levels 3, 4, and 5 in the newer CMMI framework as a mechanism that moderates the risk to performance relationship in federal technology projects. Toward this end, our results provide the following insights to managers of federal technology projects—while the implementation of CMMI 4 relative to CMMI 3 attenuates the negative performance effects of risks in the planning process only; the implementation of CMMI 5 relative to CMMI 3 attenuates the negative performance effects of risks in both planning and execution processes.

The third contribution of our study is based on our results that the intrinsic benefits of CMMI implementation in federal technology projects become particularly salient at high levels of project risk; at lower risk levels, projects with high maturity levels (e.g., CMMI 4 and CMMI 5) perform poorly on schedule and cost metrics compared to projects with low (e.g., CMMI 3) maturity levels. We surmise that at low levels of project risk, the improvements in project performance accruing from increased levels of process maturity, may not fully compensate for the costs of implementing higher CMMI levels, thereby diminishing overall project performance. A possible explanation is that Risk Management represents a process area at level 3; hence a project at level 3 implements the major risk management practices required by this process area. The high process maturity levels have process areas quantitative project management (at level 4) and organizational performance management (at level 5) which have sub-practices that are specifically related to managing risks. Since projects at levels 4 and 5 have already implemented level 3 and the Risk Management process area, the incremental benefits of implementing additional risk management sub-practices (found in levels 4 and 5) are observed only at high levels of project risks (as indicated in Figures 3–5). At low levels of project risks, the implementation of additional process areas associated with levels 4 and 5 can place significant transactional burden on the project and create overruns in project schedule and budget that may outweigh the benefits associated with attenuating the risk-performance relationship. An important managerial implication of this finding is that contracting organizations can potentially avoid wasteful expenditure of tax payer contributions in federal technology projects, by targeting higher CMMI certifications only when they plan to pursue federal technology projects with higher levels of risk.

The study’s final contribution arises from our use of an integrated measure of schedule-cost performance (SCPI) in the context of earned value management (EVM). While vendors working on federal technology projects are mandated to use EVM for tracking and reporting project progress as per industry standards and federal legislations, the use of EVM has also increased significantly in the private sector. A key advantage of this method is that it recognizes the interdependencies between project cost and schedule metrics, and allows managers to evaluate the actual value of the work accomplished against the value of the planned work while accounting for these interdependencies. This reduces subjectivity in performance evaluations, and ensures accurate reporting of the project’s progress on a periodic basis. However, there is a dearth of research in the project management literature that has used EVM for evaluating project performance. This can be attributed to the fact that EVM metrics require researchers to collect longitudinal data at the project-level (as obtained in our study), which significantly limit the availability of data sources. To that end, our study makes an important contribution to the project management literature in using EVM metrics for evaluating project performance in the empirical analysis.

6.2. Implications for Lockheed Martin and other Federal Contractors

This research is based on a sample of federal technology projects that were implemented by Lockheed Martin in the time period 2002–2012. During this period, the federal government, contractors, and industry organizations (e.g., SEI, IEEE, and ACM) had strongly supported the implementation of CMMI. In addition, there were a number of internal and industry-wide studies by government and information technology associations (e.g., Software Productivity Consortium, SEI), examining the value of CMMI. However, in recent years, following the economic recession and federal budget sequestration, resource constraints on federal technology projects have increased dramatically. Given the significant investment of organizational resources and overhead required for achieving higher process maturity levels (i.e., achieving CMMI Levels 4 and 5), federal contractors including Lockheed Martin have increasingly begun to question the benefits of higher CMMI levels. At Lockheed Martin, mainly qualitative/subjective assessments of the implications of higher process maturity levels for federal technology projects were being collected from the stakeholders involved in such projects. A more thorough, longitudinal empirical assessment was needed to derive stronger evidence of the performance impli-
cations, trade-offs, and economic significance of process maturity frameworks in the federal technology project context.

This study was specifically conducted to provide this assessment. The results of the study and its implications for practice were communicated to the managers at Lockheed Martin, some of whom were directly involved in the organization and execution of federal technology projects. In addition, as one of the co-authors of this study was a senior manager in Lockheed Martin, the study’s results were also communicated to managers within the Operations Excellence Unit (which tracks and collects quarterly data on projects) at Lockheed Martin. Our study has three important implications for the effective management of federal technology projects at Lockheed Martin.

First, the results of the study go beyond existing qualitative assessments of process maturity carried out within Lockheed Martin, by providing the company with a quantitative and rigorous econometric model to evaluate and predict the performance effects of risk and process maturity in ongoing projects. Such in-process assessments on project performance are particularly relevant to federal technology projects, given that they often span multiple quarterly periods (average duration for projects in our sample is five quarters), and involve significant investment of taxpayer contributions.

Second, the results related to the moderating effects of CMMI on the risk-performance relationship not only reinforce existing beliefs among managers about both the efficacy as well as the challenges associated with process maturity models, they also provide impetus to ongoing discussions between the company and their government customers about refining the process maturity level requirements for their projects. Highlighting these discussions, a program manager at Lockheed Martin noted, “The government perceives that CMMI 5 processes may be overkill and costly for certain projects. For many projects, we are beginning to target CMMI 3 as we do not want additional processes or costs.”

As emphasized earlier, the timeliness of these ongoing discussions cannot be overstated in the current economic scenario where funding for federal technology projects have been significantly reduced due to budget constraints. Consistent with our results regarding the moderating effects of higher CMMI levels, a series of program baseline assessment tools are currently being developed within the company to identify appropriate process maturity levels for a project based on specific characteristics of the project (e.g., project risk).

Third, our study also highlights to Lockheed Martin (and other federal contractors), the significant value of tracking and maintaining quarterly data on project risk levels. While a number of federal contractors track performance and cost information on their technology projects to report to OMB, the collection of longitudinal data on different risk types and how they vary across the life of a project is uncommon, given its resource intensive nature. Our results demonstrate to federal contractors that a systematic evaluation of the benefits and economic significance of process maturity cannot be achieved without accompanying data on project risk levels. Collecting and utilizing data on project risk, along with the econometric model developed in this study benefits the contractor, by allowing the contractor to conduct “what-if” and counterfactual analysis at varying levels of project risk and process maturity.

6.3. Limitations and Potential Extensions

Our study has the following limitations. First, the data from this study is drawn from a single organization which limits the generalizability of the findings. Though this organization is especially large, comprising of several business units and departments which execute a variety of federal technology projects, yet, an advantage of collecting objective secondary data from a single organization is that it limits noise and unobservable sources of external heterogeneity (Ehiri et al. 2005). This allows a more precise evaluation of the proposed relationships in our research model.

To the extent that federal technology projects executed in other organizations have similar characteristics, we anticipate these relationships to be robust to variations in organizational attributes. Future research can explore the relationships proposed in this paper by using multi-organizational studies. The second limitation of the study arises from the industry-specific nature of federal technology projects in the sample. As noted earlier, Lockheed Martin executes technology projects for the federal government in areas related to defense, aerospace and security systems. The inferences drawn are more likely to be applicable to federal technology projects in similar industries. Third, our sampling frame involves projects at or above CMMI 3. Whether our results will hold for technology projects that do not operate under the CMMI framework, e.g., those that use other types of process certifications (e.g., ISO 9000), and those that are below CMMI level 3, is an appropriate question for future research. Finally, although we examined three distinct and widely acknowledged risks in technology projects, it is plausible that there are other types of risks (e.g., lack of top management support for the project) that may interact with the process maturity level in a project. We encourage future research on examining the role of CMMI in the management of the adverse effects of risks on project performance.
Appendix

Table A1 Federal Legislations and Industry Standards Relevant to Federal Technology Projects

<table>
<thead>
<tr>
<th>Year</th>
<th>Legislations/standards</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>Government Performance and Results Act (GPRA)</td>
<td>Requires agencies to engage in project management tasks such as setting goals, measuring results, and reporting their progress. In order to comply with the GPRA, agencies produce strategic plans, performance plans, and conduct gap analyses of projects</td>
</tr>
<tr>
<td>1993</td>
<td>Federal Acquisition Streamlining Act (FASA)</td>
<td>Provides guidelines for streamlining the bidding and the contracting process for Federal investments</td>
</tr>
<tr>
<td>1996</td>
<td>Clinger-Cohen Act (CCA)</td>
<td>Requires the heads of federal agencies to provide a clear linkage between IT investments by the agency and the agency’s accomplishments. In addition, it establishes a process for federal agencies to better select, manage, and control their IT investments</td>
</tr>
<tr>
<td>2002</td>
<td>E-Government Act</td>
<td>To improve the management and promotion of electronic government services and processes by establishing a Federal Chief Information Officer within the Office of Management and Budget, and by establishing a framework of measures that require using Internet-based information technology to improve citizen access to government information and services</td>
</tr>
</tbody>
</table>

Table A2 Earned Value Metrics in Federal Technology Projects

**Earned Value Management:** As mentioned earlier, EVM is a project planning and control approach which compares the earned value of the project work accomplished and its associated cost against an integrated schedule and budget plan (Fleming and Koppelman 2005, Goh and Hall 2013). As such, periodic collection of data on the earned value of a project and the associated cost allows a firm to continuously monitor and evaluate the progress of the project, better predict its cost at completion, and establish milestones for contractual payments.

The earned value of a project represents the value of the project work that has been accomplished at the end of a given time period; the scheduled value of the project, in contrast, represents the value of the project work that is scheduled to be accomplished as per the baseline project plan. The two commonly used metrics in federal technology projects using EVM are: (i) Schedule Performance Index (SPI), and (ii) Cost Performance Index (CPI).

Specifically, for a project $i$ in quarter $t$ in our sample:

**SPI** is the ratio of the earned value of the work performed [or Budgeted Cost of Work Performed (BCWP)] to the planned value of the work scheduled [or Budgeted Cost of Work Scheduled (BCWS)] i.e., $SPI_{i,t} = \frac{BCWP_{i,t}}{BCWS_{i,t}}$.

**CPI** is the ratio of the earned value of the work performed [or Budgeted Cost of Work Performed (BCWP)] to the actual cost of the work performed [or Actual Cost of Work Performed (ACWP)] i.e., $CPI_{i,t} = \frac{BCWP_{i,t}}{ACWP_{i,t}}$.

Table A3 Durbin-Wu-Hausman Test for Endogeneity—Results of the First- and the Second-Stage Models

<table>
<thead>
<tr>
<th>Instrumental variable regression (first stage results)</th>
<th>Instrumental variable regression (first stage results)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept 3.739 (0.274)**</td>
<td>Year_3 -0.634 (0.249)**</td>
</tr>
<tr>
<td>Control variables</td>
<td>Year_4 0.496 (0.226)*</td>
</tr>
<tr>
<td>Project Budget 0.183 (0.032)**</td>
<td>Year_5 -0.236 (0.249)</td>
</tr>
<tr>
<td>Project Size -0.325 (0.045)**</td>
<td>Year_6 -0.621 (0.226)**</td>
</tr>
<tr>
<td>Project Labor 0.834 (0.163)**</td>
<td>Year_7 -0.036 (0.226)</td>
</tr>
<tr>
<td>Project Priority 0.736 (0.120)**</td>
<td>Year_8 0.144 (0.231)</td>
</tr>
<tr>
<td>Prime 0.241 (0.101)*</td>
<td>Year_9 0.183 (0.227)</td>
</tr>
<tr>
<td>Customer Review 0.174 (0.088)*</td>
<td>Year_10 0.656 (0.765)</td>
</tr>
<tr>
<td>Customer Perception 0.030 (0.038)</td>
<td>Year_11 1.077 (0.487)*</td>
</tr>
<tr>
<td>Change Order -0.059 (0.140)</td>
<td>Number of quarters -0.021 (0.010)*</td>
</tr>
<tr>
<td>Project Risks</td>
<td>$R^2$ 0.24</td>
</tr>
<tr>
<td>Complexity Risk 0.127 (0.041)**</td>
<td>$F$ value 7.18</td>
</tr>
<tr>
<td>Contracting Risk -0.135 (0.038)**</td>
<td>Sargan’s statistic (p-value) 14.633 (0.146)</td>
</tr>
<tr>
<td>Execution Risk -0.027 (0.039)</td>
<td>Anderson Canonical Correlation (p-value) 89.825 (0.000)</td>
</tr>
<tr>
<td>Instrumental variables</td>
<td>$N$ 519</td>
</tr>
<tr>
<td>Year_2 0.007 (0.250)</td>
<td>(continued)</td>
</tr>
</tbody>
</table>
Table A3  Continued

<table>
<thead>
<tr>
<th>Instrumental Variable Regression (Second Stage Results)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept 75.960 (2.926)**</td>
</tr>
<tr>
<td>Control variables</td>
</tr>
<tr>
<td>Project Budget 0.316 (0.475)</td>
</tr>
<tr>
<td>Project Size –1.447 (0.810)†</td>
</tr>
<tr>
<td>Project Labor 6.550 (2.417)**</td>
</tr>
<tr>
<td>Project Priority 3.372 (1.710)*</td>
</tr>
<tr>
<td>Prime 1.788 (1.539)</td>
</tr>
<tr>
<td>Customer Review 2.862 (1.211)*</td>
</tr>
<tr>
<td>Customer Perception 3.010 (0.335)**</td>
</tr>
<tr>
<td>Change Order –0.144 (0.622)</td>
</tr>
<tr>
<td>Project Risks</td>
</tr>
<tr>
<td>Complexity Risk –4.122 (0.808)**</td>
</tr>
<tr>
<td>Contracting Risk –1.422 (1.294)†</td>
</tr>
<tr>
<td>Execution Risk –4.486 (0.941)**</td>
</tr>
<tr>
<td>Process Maturity Level</td>
</tr>
<tr>
<td>CMMI 4 –1.045 (1.311)</td>
</tr>
<tr>
<td>CMMI 5 –4.118 (1.264)**</td>
</tr>
<tr>
<td>Interaction Effects</td>
</tr>
<tr>
<td>Complexity Risk × CMMI 4 4.179 (1.010)**</td>
</tr>
<tr>
<td>Complexity Risk × CMMI 5 3.249 (1.211)**</td>
</tr>
<tr>
<td>Contracting Risk × CMMI 4 8.597 (3.010)**</td>
</tr>
<tr>
<td>Contracting Risk × CMMI 5 2.410 (1.446)*</td>
</tr>
<tr>
<td>Execution Risk × CMMI 4 –1.107 (1.146)</td>
</tr>
<tr>
<td>Execution Risk × CMMI 5 2.480 (1.220)*</td>
</tr>
<tr>
<td>ResCMMI 2.377 (1.531)</td>
</tr>
</tbody>
</table>

Chi-Square 368.99**

Notes: †p < 0.1, *p < 0.05, **p < 0.01; standard errors are reported in the parentheses.

Notes

1The Office of Management Budget (OMB) is the largest office under the direct supervision of the President of the United States. The primary mission of this office is to assist the President in overseeing the preparation of the federal budget and to supervise administration in Executive Branch agencies.

2Guidelines for evaluating the performance of federal technology projects are provided by ANSI/EIA (American National Standards Institute/Electronic Industries Alliance) industry standards; specifically ANSI/EIA-748.

3Additionally, Risk Management represents a process area at level 3 and is given high priority among the best practices for managing technology projects (Jalote 2000). Similarly, process areas Quantitative Project Management at level 4, and Organizational Performance Management at level 5 have sub-practices specifically related to managing risks (CMMI for Development 2010).

4A process area represents a cluster of related practices in an area that, when implemented collectively, satisfies a set of goals considered important for making improvement in that area (CMMI for Development 2010).

5In the OM literature, studies on project risk management have conceptualized and measured risk in terms of an outcome measure or a financial measure; for example, Lederer and Mehta (2005) measure project risk in terms of its effect on the required rate of return in a project. Similarly, early studies have focused on the critical path analysis and Monte Carlo simulation methods to identify “risky tasks” and estimate the levels of risk in a project.

6For instance, an organization at CMMI level 3 performs all the process areas for level 3 in addition to the process areas of level 2; the same is true for higher CMMI levels.

7This work is accomplished at quality levels consistent with customer requirements defined in the contract.

8It is plausible that an Array project may involve a deliverable that is more modular than a deliverable in an Assembly project. Our measure of scope, however, is influenced by the number of tasks in the project. Thus, even if the resulting product has high levels of modularity, the scope of an Array will be higher than that of an Assembly as it will have more tasks that require interaction and integration. Further, Brusoni and Prencipe (2001) note that even modular products may require highly interactive organizational structures, as well as extensive interactions between team members to achieve integration, leading to higher levels of project scope.

9For robustness check, we also constructed an alternative overall measure of execution risk that captures both the count value as well as the subjective evaluations of execution risk levels in the project. The analysis results based on this overall measure of execution risk is highly consistent with those based on the count measure.

10We correct for panel-specific autocorrelation using the option corr (psar1). To correct for panel-specific heteroskedasticity, we specify the option panels (heteroskedastic).

11Deletion of outliers can affect the time-series structure across some of the projects. As an additional check, we carried out imputation of the dependent variables for the outlier observations based on the predicted scores from Model 3 in Table 3 and re-estimated the full model (Montgomery et al. 2015). The results from this revised model specification were highly consistent with those from Model 3.

12Theoretically, EAC = Project Budget/CPI. Given the high correlation (0.91) between CPI and SCPI and the absence of statistically significant differences across their distributional parameters (Mean, SD) in our sample, we substituted SCPI values in the above equation to determine EAC.

References


