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From IT Leveraging Competence to Competitive Advantage in Turbulent Environments: The Case of New Product Development

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A burning question for information systems (IS) researchers and practitioners is whether and how IT can build a competitive advantage in turbulent environments. To address this question, this study focuses on the business process level of analysis and introduces the construct of *IT leveraging competence*—the ability to effectively use IT functionalities. This construct is conceptualized in the context of new product development (NPD). IT leveraging competence is shown to indirectly influence competitive advantage in NPD through two key mediating links: *functional competencies* (the ability to effectively execute operational NPD processes) and *dynamic capabilities* (the ability to reconfigure functional competencies to address turbulent environments). Environmental turbulence is also shown to moderate the process by which IT leveraging competence influences competitive advantage in NPD. Empirical data were collected from 180 NPD managers.

Through the construct of IT leveraging competence, the study shows that the effective use of IT functionalities, even generic functionalities, by business units can help build a competitive advantage. The study also shows that the strategic effect of IT leveraging competence is more pronounced in higher levels of environmental turbulence. This effect is not direct: It is fully mediated by both dynamic capabilities and functional competencies. Taken together, these findings suggest that IS researchers should look beyond the direct effects of firm-level IT infrastructures and focus their attention on how business units can leverage IT functionalities to better reconfigure and execute business processes. In turbulent environments, focusing on these aspects is even more vital.

Key words: IT competence; information systems strategy; environmental turbulence; dynamic capabilities; functional competencies; IT-enabled business processes; new product development
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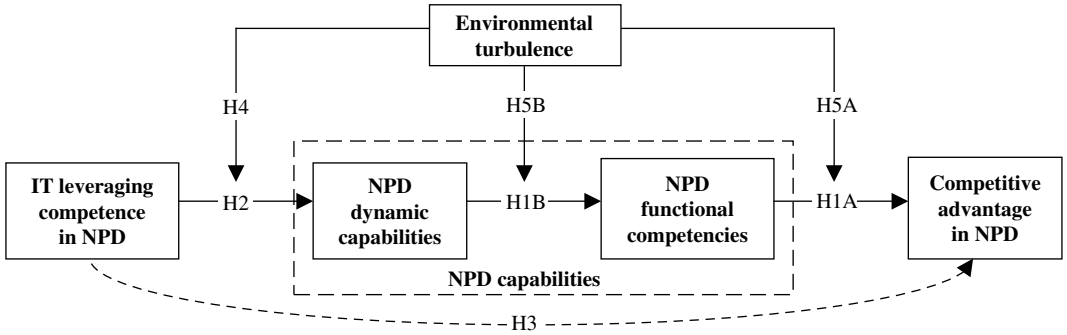
1. Introduction

A key question for information systems (IS) researchers and practitioners is how IT can build a competitive advantage (Devaraj and Kohli 2003), especially in turbulent environments (Sambamurthy et al. 2003). Despite numerous studies that examine the strategic value of IT-related constructs on competitive advantage,[1] there are still debates about the strategic potential of IT (Carr 2003).

One source of these debates is the use of various broad IT-related constructs that precluded consistent, unambiguous, and readily comparable studies on the strategic role of the IT artifact. A related source of contention is the firm level of analysis that may have obscured the effects of IT on specific firm processes. Also, the literature has predominantly viewed IT capability as arising from within the IT unit, alas ignoring the role of business users (or "clients") to strategically leverage IT. To address these three sources of contention, this study develops a process-level construct of IT following Ray et al. (2005) who argue that a process (as opposed to a firm) level of analysis is the most appropriate level for observing the strategic effects of IT. Building on the IT capability literature, we introduce and develop

[1] For a review of studies on the strategic role of IT-related measures, see Kohli and Devaraj (2003).

Figure 1 The Proposed Research Model



the construct of *IT leveraging competence* (the ability to effectively use IT functionalities to support IT-related activities) in the new product development (NPD) context. The proposed IT leveraging competence in NPD construct is defined as the ability of NPD work units to effectively use IT functionalities to support the units' IT-enabled NPD activities. NPD is an information and knowledge intensive process (Madhaven and Grover 1998, Nambisan 2003) and is likely to be facilitated by the effective use of IT functionalities. Having developed a specific construct of IT leveraging competence specifically for the NPD process by focusing on the IT capability of NPD work units outside of the IT unit, we proceed to examine its impact on competitive advantage in different degrees of environmental turbulence.

Another open debate in the literature is whether IT-related constructs influence competitive advantage directly or indirectly (Wade and Hulland 2004).[2] Recent literature has questioned a direct impact of IT-related constructs on competitive advantage, arguing for the existence of mediating links (e.g., Barua et al. 1995, Devaraj and Kohli 2003, Soh and Markus 1995). Extending this indirect view, we propose a research model to delineate the mechanisms by which IT leveraging competence in NPD helps build a competitive advantage in turbulent environments. We propose two NPD capabilities as *missing links* in the IT leveraging competence-competitive advantage relationship (Figure 1). First, *NPD functional competencies* (the ability to effectively execute operational NPD activities) are proposed to have a direct impact on competitive advantage. Second, *dynamic capabilities* (the ability to integrate, build, and reconfigure existing functional competencies to address turbulent environments; Teece et al. 1997) are hypothesized to have an indirect impact on competitive advantage in NPD by reconfiguring NPD functional competencies.

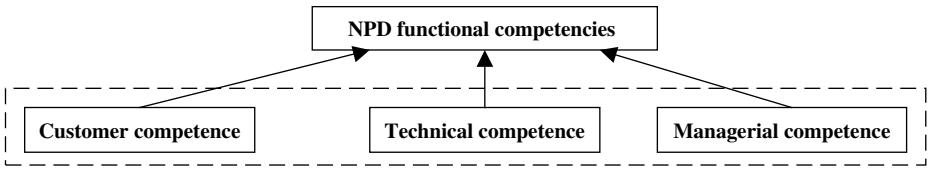
The paper proceeds as follows: Section 2 reviews the role of NPD capabilities (functional competencies and dynamic capabilities) in competitive advantage in NPD. Section 3 introduces and conceptualizes the proposed construct of IT leveraging competence in NPD. Section 4 explains how IT leveraging competence indirectly influences competitive advantage in NPD through the two proposed NPD capabilities. Section 5 hypothesizes the moderating role of environmental turbulence in the proposed structural model. Section 6 describes the research methodology and the field study used to test the proposed hypotheses, and §7 presents the data analysis and results. Finally, §8 discusses the study's contributions and implications for theory and practice.

2. Competitive Advantage in NPD

We have chosen the context of NPD to examine the relationship between IT leveraging competence and competitive advantage. NPD is the process of bringing a new product to market, including idea generation and idea screening, concept development and testing, business analysis, prototype and market testing, technical implementation, and plans for product commercialization and launch (http://en.wikipedia.org/wiki/New_product_development). NPD is a strategic process wherein firms integrate disparate inputs from R&D scientists, engineers, and marketers to jointly

[2] For a summary of papers on the direct and indirect effects of IT on competitive advantage, see Wade and Hulland (2004, p. 125).

Figure 2 Proposed Nature of NPD Functional Competencies



develop and launch new products (Clark and Fujimoto 1991).[3]

Competitive advantage in NPD is a more unambiguous measure of competitive advantage than an aggregate firmwide competitive advantage measure. As Ray et al. (2004, p. 24) explain, "firms can have a competitive advantage in some business activities and competitive disadvantages in others." Therefore, competitive advantage in NPD is herein introduced as the study's ultimate dependent variable, and the study is conducted at the process level with the NPD work unit as the unit of analysis, which can be either intrafirm or interfirm (Sivadas and Dwyer 2000).

Competitive advantage in NPD is achieved by concurrently achieving *product effectiveness* (quality and innovativeness) and *process efficiency* (time to market and low cost) (Kusunoki et al. 1998). Both process efficiency and product effectiveness have been individually linked to a firm's profitability (Henard and Szymanksi 2001). The NPD literature has shown that successful NPD work units must offer an attractive combination of product cost and quality (Atuahene-Gima and Li 2004, Brown and Eisenhardt 1995, Clark and Fujimoto 1991).

The NPD context has two types of NPD capabilities (functional competencies and dynamic capabilities; Danneels 2002), which are proposed to influence competitive advantage in NPD, as explained below.

2.1. NPD Functional Competencies and Competitive Advantage in NPD

The NPD literature views functional competencies as the basis on which new products are built (e.g., Clark and Fujimoto 1991). *NPD functional competencies* are defined as the ability to effectively execute operational NPD processes relative to the competition.

For simplicity, the key NPD functional competencies are customer, technical, and managerial competencies (Danneels 2002). First, *customer competence* involves understanding customer preferences, evaluating competing products, and formulating customer incentives. It requires proficiency in designing product sales, distribution, pricing, and advertising (Urban and Hauser 1993). Second, *technical competence* involves evaluating the technical feasibility of new product designs, testing prototypes, and assessing technical specifications (Pisano 1994). Third, *managerial competence* involves monitoring progress, designing worker incentives, and managing conflicts. We conceptualize NPD functional competencies as a formative second-order model (Figure 2).[4] A formative model is deemed appropriate as these three first-order NPD functional competencies facilitate or "form" the second-order overall NPD functional competence. Also, the three NPD functional competencies are complementary to each other (Nerkar and Roberts 2004), and they cumulatively combine to serve the overall purpose of developing new products (Song et al. 2005). Finally, because a change in any functional competence does not necessarily cause an equal change in the other competencies, a reflective model seems unlikely. Therefore, a formative second-order model is proposed.

The NPD and marketing literatures have shown that superior NPD functional competencies are the direct basis on which competitive new products are developed and competitive advantage in NPD is achieved (e.g., Clark and Fujimoto 1991, Song et al. 2005). NPD work units with superior functional competencies are capable of building technically superior products that better meet customer needs (e.g., Kusunoki et al. 1998, Song and Parry 1997). In

[3] For a detailed literature review of the NPD literature, please see Krishnan and Ulrich (2001) and Brown and Eisenhardt (1995).

[4] The relationship between first- and second-order constructs can be of two types—reflective or formative. Reflective structures assume that the latent second-order factor causes the first-order factors. For formative structures, the second-order factor is conceived to be caused by the first-order factors that each represents a unique contribution to the second-order factor (Chin 1998). Please see Diamantopoulos and Winklhofer (2001) and Edwards (2001) for a review.

contrast, outdated functional competencies (or "rigidities") (Leonard-Barton 1992) result in poor process efficiency and product effectiveness, and thus result in inferior new products.

In summary, there is substantial theoretical and empirical evidence in the NPD and marketing literatures that superior NPD functional competencies serve as the platform for competitive advantage in NPD (e.g., Song et al. 2005). Because NPD functional competencies are herein captured relative to the competition, *competitive advantage in NPD* denotes developing products superior to those of the competitors.

Hypothesis 1A (H1A). *Superior NPD functional competencies positively influence competitive advantage in NPD.*

2.2. Dynamic Capabilities, Functional Competencies, and Competitive Advantage

In contrast with functional competencies, which help firms undertake the operational day-to-day NPD activities, dynamic capabilities are strategic processes whose objective is to shape functional competencies.[5] *Dynamic capabilities* have been defined as "the ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments" (Teece et al. 1997, p. 517). Dynamic capabilities have been viewed as strategic options (Kogut and Zander 1996), which allow firms to shape their existing functional competencies when the opportunity or need arises.

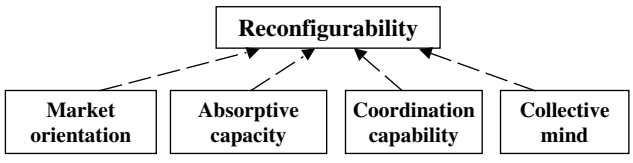
In NPD, dynamic capabilities help firms reconfigure existing NPD functional competencies so they can build products that better match emerging customer needs and take advantage of technological breakthroughs (Iansiti and Clark 1994). In other words, NPD dynamic capabilities help firms select the right product concept and shape their requisite NPD functional competencies to operationally develop the product right.

[5] Both dynamic capabilities and functional competencies are composed of a complementary set of resources that reflect the effectiveness in executing business processes. While NPD capabilities and NPD competencies are used interchangeably in this paper, for clearness, we use the term capabilities for dynamic capabilities and competencies for functional ones.

Pavlou and El Sawy (2006) identify five processes that constitute dynamic capabilities in NPD: reconfiguring resources to better match the environment, sensing the environment, learning, coordinating activities, and integrating interaction patterns. These five processes are conceptualized as a two-level framework that distinguishes between the goal reconfiguration process and the four enabling processes (sensing, learning, coordinating, integrating), whose role is to enable the goal reconfiguration process. Since capabilities and competencies reflect the effectiveness in executing business processes (Nelson and Winter 1982), the effectiveness in executing these five processes is driven by a set of capability constructs. Effectively executing the reconfiguration process is operationalized with a second-order construct of reconfigurability. Effectively sensing the environment is reflected by market orientation (Kohli and Jaworski 1990), effectiveness in learning by absorptive capacity (Cohen and Levinthal 1990), effective coordination by coordination capability (Malone and Crowston 1994), and integrating interaction patterns by collective mind (Weick and Roberts 1993). A formative model (Figure 3) is proposed to model dynamic capabilities because each first-order capability is posited to enable or "form" the second-order reconfigurability construct. Also, the first-order capabilities are inherently dynamic, and a change in a first-order capability would not necessarily imply an equal change in the other first-order capabilities, rendering a reflective model as less likely.

Within the context of NPD, it is also necessary to distinguish between dynamic capabilities and functional competencies. First, while market orientation helps NPD work units to generate, disseminate, and respond to market intelligence to help propose a product that matches customer needs, customer competence helps NPD work units to sell the proposed product by designing marketing, sales, pricing, and advertising programs. Second, while absorptive

Figure 3 The Proposed Nature of NPD Dynamic Capabilities



capacity helps NPD work units to acquire, assimilate, transform, and exploit existing resources to generate new knowledge, technical competence helps NPD work units to practically develop the product by testing and evaluating its technical specifications. Finally, while coordination capability and collective mind help NPD work units to manage dependencies among resources and tasks to create and implement new ways of performing NPD activities, managerial competence helps them administer NPD activities by monitoring progress, designing worker incentives, and managing conflicts. In summary, dynamic capabilities are more strategic processes that help NPD work units to introduce the concept for new products, while the functional competencies are more operational processes that help NPD work units to operationally design, manage the development of, and launch the new products.

To interrelate dynamic capabilities with functional competencies and competitive advantage in NPD, we draw on the strategy literature that specifies the role of dynamic capabilities as reconfiguring ineffective functional competencies and shaping more promising ones that better match the environment, better, faster, and cheaper than the competition (Eisenhardt and Martin 2000). Applied to NPD, work units compete on the basis of the appropriateness, timeliness, and efficiency by which their NPD functional competencies can be shaped into superior new functional competencies that better match the environment. For example, by sensing the environment faster and cheaper than the competition, NPD work units are more likely to spot and capitalize on new concepts for new products (Day 1994). Having selected superior new product concepts that are likely to match what customers need (superior market orientation), NPD work units will then become more effective in designing superior sales programs (superior customer competence). Also, NPD work units that can learn faster and more efficiently than the competition (superior absorptive capacity) will become more effective in developing superior product designs that would make it easier to physically build such new products (Danneels 2002). Finally, NPD work units with a superior coordination capability and collective mind are more likely to become more effective in synchronizing their tasks and resources, and their NPD managers will become more effective in administering their day-to-day activities (superior managerial competence). In sum, superior NPD dynamic capabilities are likely to lead to superior NPD functional competencies.

Hypothesis 1B (H1B). *NPD dynamic capabilities positively influence superior NPD functional competencies*.

H1A and H1B suggest that NPD dynamic capabilities and NPD functional competencies jointly influence competitive advantage in NPD. This is because competitive advantage in NPD at any point in time directly draws from NPD functional competencies, which will, over time, depend on dynamic capabilities in NPD. Empirical evidence in NPD shows that firms with dynamic capabilities build superior new products (Henderson and Cockburn 1994), and improve their product quality and cycle time (Iansiti and Clark 1994). In contrast, NPD work units that are slow in reconfiguring their NPD functional competencies are shown to end up with rigidities (Leonard-Barton 1992). In sum, NPD dynamic capabilities yield a sustainable competitive advantage through superior new NPD functional competencies, whose goal is a series of temporary competitive advantages through specific new products. Having established the interrelationships among dynamic capabilities, functional competencies, and competitive advantage, we proceed to examine how IT leveraging competence can be integrated with competitive advantage in NPD.

3. IT Leveraging Competence in NPD

We introduce and develop the construct of IT leveraging competence in NPD by drawing on the IT capability literature, taking into account the idiosyncrasies of the NPD context, and also by following Ray et al. (2005), who recommend examining IT capability at the process (and not at the firm) level since "the impact of IT should be assessed where the first order effects are expected to be realized" (p. 626).

The IT capability literature is rooted in the resource based view. The IT capability literature (summarized in Table 1), generally argues that various IT-related resources combine to form an IT capability that is valuable, rare, nonimitable, and nonsubstitutable (Mata et al. 1995). Taking this perspective, Bharadwaj (2000) defines IT capability as "the ability to mobilize

Table 1 IT-Related Resources that Combine to Form IT Capability

Studies (in chronological order)	IT-related resources that combine to form IT capability
Mata et al. (1995)	Access to capital, proprietary technology, technical IT skills, managerial IT skills
Ross et al. (1996a)	Reusable technology base (technology asset) IT-business partnering relationship (relationship asset) IT human resources (human asset)
Powell and Dent-Micallef (1997)	Technology (IT) resources Complementary IT human resources Complementary business resources
Feeny and Willcocks (1998)	Design of IT infrastructure, business and IT vision, delivery of IS services
Bharadwaj et al. (1999)	IT infrastructure, business process integration, internal IT partnerships, external IT partnerships, IT management, strategic vision of IT
Bharadwaj (2000)	IT infrastructure, human IT resources, IT-enabled intangibles
Sambamurthy et al. (2003)	IT investment scale, IT capabilities (as Bharadwaj 2000).
Tippins and Sohi (2003)	IT objects (hardware, software, and support personnel) IT knowledge (technical knowledge about IT systems) IT operations (IT utilization to manage information)

and deploy IT-based resources in combination or copresent with other resources and capabilities" (p. 171).

IT capability has been viewed as a complex, multidimensional construct, and the literature has proposed several specific IT-related resources that combine to form an IT capability. The literature suggests that IT capability has three key dimensions: (a) the acquisition of IT resources, such as technology assets (Ross et al. 1996), IT objects (Tippins and Sohi 2003), and the overall IT infrastructure (Bharadwaj 2000, Feeny and Willcocks 1998); (b) deployment of IT resources through tight IT-business relationships, such as IT-business partnering (Ross et al. 1996), IT partnerships (Bharadwaj et al. 1999), and business-IT vision (Feeny and Willcocks 1998); and (c) leveraging of IT resources, such as technical IT skills (Mata et al. 1995, Tippins and Sohi 2003, Ray et al. 2005) and human IT resources (e.g., Bharadwaj 2000, Powell and Dent-Micallef 1997, Ross et al. 1996). Based on these three dimensions, Bharadwaj et al. (2002, p. 4) define IT capability as the "firm's ability to acquire, deploy, and leverage its IT resources to shape and support its business strategies and value chain activities."

This three-dimensional representation of IT capability views the construct at the firm level of analysis, and views the IT capability construct to be predominantly drawn from within the IT unit. However, to develop an IT capability construct specifically for the NPD context, we need to adapt the firm-level IT capability to the NPD process and focus on the leveraging capabilities of NPD work units as business users (or clients). Because the acquisition and deployment dimensions of IT capability are largely based on the IT investment decisions of IT executives and are primarily implemented by IT staff within the IT unit, we argue that the acquisition and deployment dimensions of IT capability are unlikely to differentiate among NPD work units.[6] Hence, we focus on the leveraging dimension of IT capability, which is more likely to help NPD work units differentiate themselves from competing work units, and to build a competitive advantage in NPD.

In the past decade, the NPD context has been infused with NPD software packages (Nambisan 2003). Today's NPD packages can be viewed as generic technologies (Ray et al. 2005) that can be readily acquired from NPD software vendors, and that can be easily deployed with little effort and expertise. Also, the deployment of NPD software tools does not require tight IT-business partnerships to be successful.[7] Conversations with NPD managers and NPD software vendors confirm that there is little variation among commercial NPD tools. These conversations also confirmed that the acquisition and deployment of NPD software packages is a rather straightforward task that is handled by this company's internal IT unit. Therefore, the leveraging of IT functionalities by

[6] Acquiring and deploying NPD technologies are likely to improve performance in an absolute sense compared with not having acquired and deployed such NPD technologies. However, because most NPD work units have acquired and implemented such technologies, these two dimensions are unlikely to strategically differentiate across competing NPD work units.

[7] In contrast, the acquisition and deployment of an integrated firmwide IT infrastructure requires tight IT-business partnerships and substantial time and expertise, and it is thus likely to differentiate across firms (e.g., Feeny and Willcocks 1998).

NPD work units as clients is herein viewed as the primary source of differentiation in NPD work units. Our view of IT leveraging competence in NPD is thus consistent with the IT capability literature (Table 1), but it takes into account the process level of analysis and the idiosyncrasies of the NPD context to conceptualize a specific construct of IT capability outside of the IT unit as the leveraging competence of clients.

Most important, because the acquisition, deployment, and leveraging dimensions of IT capability follow a sequential progression, the leveraging of an NPD package draws directly from its acquisition and deployment. If a poor NPD package was purchased or was poorly deployed by the IT unit, or both, the ineffective acquisition and deployment are likely to undermine its effective leveraging by the NPD work unit. Thus, even if our view only focuses on the leveraging dimension of the overall IT capability construct, our concept of IT leveraging competence in NPD largely accounts, albeit indirectly, for the acquisition and deployment dimensions.

Following these requirements and based on the notion that leveraging of IT resources is the primary differentiating factor among NPD work units, we define *IT leveraging competence in NPD* as the ability of NPD work units to effectively use IT functionalities to support IT-enabled NPD activities. IT leveraging competence in NPD thus describes the ability of NPD work units to be aware of what IT functionalities have to offer, to understand when to use them if they may be useful, and (when they decide to use them) to do so effectively by taking advantage of their specific IT functionalities. Beyond the focal NPD context, IT leveraging competence would be described as the ability to effectively leverage IT functionalities to support specific IT-enabled activities. Our definition is therefore most consistent with Tippins and Sohi (2003) who describe their notion of IT competency as the extent to which a firm is knowledgeable about and effectively utilizes IT tools to manage information within the firm.

In addition to distinguishing IT leveraging competence in NPD from firmwide IT capability, we also need to distinguish it from other IT-related constructs. First, IT leveraging competence in NPD is different from IT functionality and IT resources because IT leveraging competence in NPD reflects the effective use of NPD IT resources and functionalities, not merely their existence, the quality of NPD packages, or any unique IT functionalities. Second, IT leveraging competence in NPD is different from IT investments or IT spending in NPD. Mere IT investments and spending do not guarantee that the acquired and deployed NPD packages will be properly understood and effectively used. Investing in IT without effectively leveraging these investments is unlikely to enhance performance (Tippins and Sohi 2003). Empirical evidence has shown no consistent relationship between a firm's IT investments and its profitability (Mata et al. 1995, Powell and Dent-Micallef 1997, Tippins and Sohi 2003). Whereas IT functionality, resources, and investments can be easily copied, imitated, or duplicated by the competition (Clemons 1991), we view IT leveraging competence in NPD as a rare, valuable, nonimitable, and nonsubstitutable capability that is likely to be heterogeneously distributed across NPD work units.

3.1. The Dimensions of IT Leveraging Competence in NPD

To identify the primary dimensions of IT leveraging competence in NPD, we first reviewed the academic NPD literature (e.g., Nambisan 2003, Rangaswamy and Lilien 1997). Our starting point was Nambisan's (2003) proposed dimensions of IT tools in NPD (process management; project management; information and knowledge management; and collaboration and communication). With these dimensions in mind, we examined over 30 commercial NPD packages for additional dimensions, and also for IT functionalities that would suggest the need for including, integrating, or dropping any dimensions. Our review confirmed Nambisan's (2003) four dimensions, but it suggested the need to integrate process and project management under a single dimension. Summarizing this review, the systems that NPD work units commonly employ are (1) project and resource management systems; (2) knowledge management systems; and (3) cooperative work systems. Table 2 describes what constitutes the effective use of these NPD systems.

Drawing on Table 2, we propose three key dimensions of IT leveraging competence in NPD: (a) effective use of project and resource management systems

Table 2 Key IT-Enabled NPD Activities and Effective Use of NPD Systems

NPD systems	Key IT-enabled NPD activities	Effective use of NPD systems
Project and resource management systems	Scheduling and time management	• Quickly prioritizing tasks and keeping deliverables on track to ensure realistic schedules
	Resource management	• Analyzing and measuring work, tasks, and resources
	Task assignment	• Knowing the true availability of people, skills, and resources to enable appropriate task assignment
Knowledge management systems	Coding and sharing of knowledge	• Leveraging IT tools for storing, archiving, retrieving, sharing, and reusing project information and best practices
	Creation of knowledge directories	• Creating online knowledge communities (e.g., virtual discussion forums) focused on new ideas and products
	Knowledge networking	• Leveraging IT tools for locating relevant expertise
Cooperative work systems	Conveyance	• Describing and defining product structures, configurations, and routines
	Presentation	• Effectively manipulating the format of our contributions
	Convergence	• Adequacy of using IT tools (e.g., desktop sharing) for simultaneously working together in real-time

(PRMS), (b) effective use of knowledge management systems (KMS), and (c) effective use of cooperative work systems (CWS), as described below.

3.1.1. Effective Use of PRMS. PRMS provide IT functionalities designed for the project and process management of NPD projects (McGrath and Iansiti 1998), such as Oracle Project Management tools.[8] PRMS have three key functionalities: First, the scheduling and time management functionality, such as that provided by IBM's NPD planning tools,[9] helps NPD work units obtain real-time information on project status, integrate dispersed information, and monitor performance. It also helps work units visualize project status, monitor the progress of workflows, and track project deliverables. Second, the resource management functionality, such as that provided by SAP's Asset Life-Cycle Management,[10] helps NPD work units manage their shared resource dependencies by breaking down the project into smaller tasks and identifying matching resources. It also provides real-time information on the availability, usage, and cost of various resources to achieve the best possible resource allocation. Third, the task assignment functionality helps NPD work units link project deliverables to tasks, decide which resources to use for each task, and align tasks among people to avoid task duplication. It also models the true availability of people, skills, and resources so that multiple tasks can be performed in parallel. In summary, since these three PRMS functionalities can help support the NPD process in value-adding ways, the effective use of PRMS is proposed as a key facet of IT leveraging competence in NPD.

3.1.2. Effective Use of KMS. KMS have a potential role in supporting knowledge management activities in NPD. For example, Dassault's Enovia[11] is designed to facilitate the acquisition, assimilation, transformation, and exploitation of tacit and explicit knowledge. KMS have three key functionalities: First, the knowledge coding and sharing functionality helps NPD work units capture, codify, assimilate, and share knowledge, such as product designs and engineering data. It also allows NPD work units to permanently store their project histories (e.g., discussions and work data) in content repositories to make them accessible for reuse. Second, the functionality for the creation of knowledge directories, such as that provided by data warehousing systems, helps NPD work units gain easy access to project information and best practices from prior projects. Third, the knowledge networking functionality enables communication forums and knowledge communities that help NPD work units discuss new product ideas. It also helps NPD work units locate relevant expertise through visualization IT technologies. Because these KMS functionalities can enhance the NPD process in value-adding ways, the effective use of KMS is proposed as a key facet of IT leveraging competence in NPD.

[8] http://www.oracle.com/applications/projects/index.html?management.html

[9] http://www.1.ibm.com/solutions/plm/doc/jsp/indseg/cross/planning/

[10] http://www.sap.com/solutions/plm/keycapabilities/asset.asp

[11] http://plm.3ds.com/10+M5a090141a36.0.html

3.1.3. Effective Use of CWS. CWS, or groupware, are technologies that enable collaborative work by enabling group communication across time and space. CWS have three key functionalities: First, the conveyance functionality, such as Oracle's CADView,[12] enables data-based collaboration, content management, and sharing ideas. For example, CAD visualization tools allow NPD work units to concurrently examine engineering drawings and product structures from any location. Second, the presentation functionality, such as that found in filtering, structuring, and modeling tools, enables NPD work units to transform their tacit ideas into graphic images. By sorting, structuring, and analyzing individual contributions into a collective design, presentation systems allow NPD work units to manipulate the format of their individual contributions and give new meaning to existing contributions. Third, the convergence functionality, such as Oracle's Project Collaboration tools[13] can clarify assumptions, elicit tacit knowledge, and construct product histories by enabling NPD work units to work together and review product designs in real time. This functionality helps NPD work units brainstorm, converge their ideas, find solutions for new products, and reach group consensus. Because these CWS functionalities can help enhance the NPD process in value-adding ways, the effective use of CWS is proposed as a key element of IT leveraging competence in NPD.

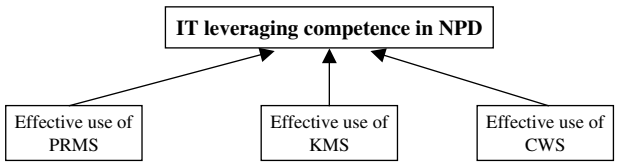
3.2. IT Leveraging Competence in NPD as a Formative Higher-Order Model

IT leveraging competence in NPD is viewed as a latent construct, conceptualized as a second-order factor formed by a set of three first-order facets (effective use PRMS, KMS, CWS). Therefore, to describe the nature of IT leveraging competence in NPD, we propose a formative second-order model (Figure 4), which is a coherent and parsimonious depiction of the multidimensional nature of IT leveraging competence in NPD.

[12] http://www.oracle.com/applications/B2B/Product_Development/index.html?CAD3D.html

[13] http://www.oracle.com/applications/projects/index.html?collaboration.html

Figure 4 The Proposed Higher-Order Model for IT Leveraging Competence in NPD



The second-order model is implied by the complementarities among IT functionalities in NPD systems (Rangaswamy and Lilien 1997). Because there is convergence of these three related functionalities in NPD packages (Nambisan 2003), the proposed dimensions cumulatively contribute to a higher-order IT leveraging competence, which can more parsimoniously explain their cumulative effect (as opposed to three distinct individual effects). Using a similar logic, Bharadwaj et al. (1999) also view firmwide IT competence as a second-order factor formed by first-order factors. Moreover, the effective use of PRMS, KMS, and CWS is likely to change over time and be affected in a different way by other factors. Because NPD work units are likely to use these IT systems with various degrees of effectiveness, the effective use of each system is proposed to affect IT leveraging competence in NPD in a formative fashion. Besides, since a change in the ability to leverage any single system does not necessarily imply an equal change in the ability to leverage another system, a reflective model is less likely. Thus, a formative second-order model is deemed appropriate for viewing the construct of IT leveraging competence in NPD.

4. IT Leveraging Competence and Competitive Advantage in NPD

To delineate how IT leveraging competence in NPD links to competitive advantage in NPD, we first discuss the direct impact of IT leveraging competence on NPD capabilities, and we then discuss the mediating role of NPD capabilities in the relationship between IT leveraging competence and competitive advantage.

4.1. Linking IT Leveraging Competence with NPD Capabilities

Drawing on the logic that the effective use of IT functionality can facilitate information-intensive and

knowledge-intensive processes, we propose IT leveraging competence in NPD to support NPD capabilities. Because NPD capabilities are information and knowledge intensive (Madhaven and Grover 1998), they can be enhanced by the effective leveraging of IT functionalities (McGrath and Iansiti 1998, Nambisan 2003). First, IT leveraging competence in NPD can support information processing through enhanced communication and increased efficiency of information sharing. Second, the efficiency, scope, and flexibility of NPD capabilities can be enhanced by IT leveraging competence. IT leveraging competence can facilitate the efficiency of NPD capabilities by facilitating rapid and reliable knowledge sharing (Alavi and Leidner 2001), it can increase their scope by increasing knowledge reach and richness (Sambamurthy et al. 2003), and it can enhance their flexibility by enhancing the accessibility and availability of knowledge (Zahra and George 2002).

While both types of NPD capabilities are information and knowledge intensive capabilities that can be potentially enhanced by the effective use of IT functionalities, dynamic capabilities rely on more general information and knowledge than functional competencies that tend to use more firm-specific knowledge. Therefore, the direct impact of IT-leveraging competence in NPD is expected to be on dynamic capabilities by leveraging IT functionalities embedded in PRMS, KMS, and CWS to manage general knowledge; in contrast, NPD functional competencies are unlikely to be enhanced by the effective use of PRMS, KMS, and CWS, but they are more likely to be enhanced by other customized IT systems that manage firm-specific knowledge.

4.1.1. IT Leveraging Competence and NPD Dynamic Capabilities. IT leveraging competence in NPD is conceptualized to directly enhance each of the four first-order dynamic capabilities—market orientation, absorptive capacity, coordination capability, and collective mind.

Market Orientation. IT leveraging competence in NPD is proposed to enhance market orientation. First, by accelerating the efficiency by which information is acquired by the environment, the effective use of KMS enables NPD work units to stay current with market intelligence. Second, the effective use of CWS enables information flows, thus enhancing the ability of NPD work units to disseminate market intelligence. Finally, the effective use of CWS enables NPD work units to collectively assess market intelligence and test various new product concepts, thus enabling their responsiveness to market intelligence. In sum, by enhancing the ability of NPD work units to generate, disseminate, and respond to market intelligence, IT leveraging competence in NPD enhances market orientation.

Absorptive Capacity. IT leveraging competence in NPD is proposed to influence absorptive capacity. First, by analyzing, coding, and sharing tacit knowledge, the effective use of KMS makes NPD work units more competent in acquiring product-related knowledge. Second, by facilitating easy access to stored knowledge, the effective use of KMS enhances the competence of NPD work units in articulating, interpreting, and synthesizing new and stored knowledge, thus enabling knowledge assimilation. Third, the effective use of CWS can enhance the problem-solving capability of NPD work units and the units' ability to generate new thinking (Tippins and Sohi 2003), thereby enabling knowledge transformation. Fourth, the effective use of CWS can enhance the ability of NPD work units to pursue new product initiatives and find new solutions (McGrath and Iansiti 1998), thus enabling superior knowledge exploitation. In summary, by enhancing the ability of NPD work units to acquire, assimilate, transform, and exploit new knowledge, IT leveraging competence can enhance absorptive capacity.

Coordination Capability. IT leveraging competence in NPD is proposed to enhance coordination capability. First, by making it easier to identify available resources and providing visibility of real-time project data, the effective use of PRMS can enhance the ability of NPD work units to quickly and accurately allocate resources to project tasks. Second, the effective use of scheduling and time management functionalities in PRMS makes NPD managers more capable in appointing NPD workers to relevant tasks and enables them to better monitor the performance of NPD workers. Third, by providing real-time information on project status and enabling aggregate project portfolios, the workflow capabilities of PRMS can help NPD work units become more capable in identifying synergies among their resources and tasks, better synchronizing their activities, and executing their collective activities

in parallel (Sethi et al. 2001). By enhancing the ability of NPD work units to allocate resources, assign tasks, and synchronize activities, IT leveraging competence in NPD can enhance coordination capability.

Collective Mind. Because a collective mind is developed by integrating the thought worlds of multiple individuals, IT leveraging competence is expected to facilitate a collective mind in NPD work units by making knowledge visible and accessible and by providing a common language for communication (Boland and Tenkashi 1995). First, by making it easy to share knowledge, the conveyance functionality in CWS enables NPD workers to be forthcoming in sharing their individual knowledge. Second, the effective use of presentation functionality in CWS allows NPD work units to achieve rich communication, sensemaking, and perspective sharing. Hence, by making the social environment of online group conversations richer through presentation functionalities, the effective use of CWS enables NPD workers to stay in touch with what others do, to visualize how they fit in, and to learn how their work affects others. Third, by facilitating shared structures of interaction, the effective use of convergence functionality in CWS enhances the ability of NPD work units to build shared interpretations and reach consensus. In sum, by enhancing the ability of NPD work units to contribute, represent, and rely on the group system, IT leveraging competence in NPD can enhance the collective mind of NPD work units.

Integrating the proposed impact of the various dimensions of IT leveraging competence in NPD on the respective elements of the four first-order dynamic capabilities, we formally hypothesize:

Hypothesis 2 (H2). *IT leveraging competence in NPD positively influences NPD dynamic capabilities.*

4.1.2. IT Leveraging Competence and NPD Functional Competencies. IT leveraging competence in NPD specifically aims to enhance information- and knowledge-intensive NPD capabilities. However, the operational nature of the NPD functional competencies is unlikely to be enhanced by the effective use of PRMS, KMS, and CWS, whose primary role is to process information and manage knowledge. For example, while *market orientation* (ability to generate, disseminate, and respond to market intelligence) can be enhanced by IT leveraging competence (as justified above), *customer competence* (ability to design marketing programs and formulate customer incentives) is unlikely to be directly enhanced by the effective use of IT functionalities in NPD. Accordingly, while *absorptive capacity* (ability to acquire, assimilate, transform, and utilize knowledge) can be directly enhanced by IT leveraging competence in NPD, *technical competence* (ability to evaluate new designs, assess technical specifications, and test prototypes) is unlikely to be facilitated by the effective use of IT functionalities. Accordingly, *managerial competence* (ability to design incentives, monitor progress, and manage conflicts) is also unlikely to be directly enhanced by IT leveraging competence in NPD. In sum, because NPD work units cannot get much benefit by leveraging PRMS, KMS, and CWS to enhance their competence in undertaking their three basic operational activities, IT leveraging competence in NPD is not proposed to enhance the NPD functional competencies.

Even if IT leveraging competence in NPD is not expected to directly enhance functional competencies in NPD, this does not suggest that NPD functional competencies or functional competencies in general cannot be enhanced by the effective use of IT. First and most important, NPD work units use different IT systems to manage the information and knowledge needed to perform their operational processes. For example, designing customer programs and formulating incentives are usually performed by firm-specific customer IT systems that are often specific to the firm's customer base (e.g., consumers versus distributors). Also, evaluating product designs and testing prototypes is often facilitated by proprietary product testing equipment that are particular to the company's focal products (e.g., automobiles versus consumer goods). Designing incentives and managing conflicts are often facilitated by firmwide management applications that may also be used in NPD. Therefore, the ability to execute operational activities may be enhanced by various customized IT systems that focus on firm-specific knowledge, but it is not directly supported by the focal IT functionalities present in generic NPD software packages that are leveraged to manage general knowledge. Second, there is a close relationship between dynamic capabilities and functional competencies (H1B), which suggests that the impact of IT leveraging competence

in NPD may be evident on NPD functional competencies, albeit indirectly. These arguments suggest that the direct impact of IT leveraging competence in NPD is on the information- and knowledge-intensive NPD dynamic capabilities. The impact of IT leveraging competence in NPD on functional competencies is thus expected to be indirect, mediated by NPD dynamic capabilities.

4.2. Indirect Impact of IT Leveraging Competence on Competitive Advantage in NPD

We propose an indirect impact of IT leveraging competence in NPD on competitive advantage through the mediating role of NPD capabilities. Following the process view of organizations and Porter's (1985) value chain model, NPD capabilities (NPD functional competencies and NPD dynamic capabilities) are viewed as resources enabling primary activities because they are directly involved with the product's physical development and delivery. On the other hand, IT leveraging competence in NPD can be viewed as a resource enabling secondary activities because it is not directly involved in a product's physical creation and delivery, but it has an indirect, supporting impact on the primary activities by directly enhancing the NPD capabilities. Grant (1995) proposes a hierarchy of firm capabilities in which MIS-related functional competencies are viewed as the platform on which other higher-order organizational capabilities are built. Grant suggests that the higher the order of firm capabilities, the more immediate is their impact on competitive advantage. Building on Grant's view, IT leveraging competence in NPD is proposed as the basis for (higher-order) NPD capabilities, and is thereby farther away from competitive advantage in NPD.

Applying these arguments to NPD, the role of IT leveraging competence is to enhance NPD capabilities (dynamic capabilities and, in turn, functional competencies), and its direct impact should be observed on the NPD capabilities, and not on the outcomes of the NPD capabilities (that is, competitive advantage in NPD). These arguments suggest an indirect impact of IT leveraging competence on competitive advantage in NPD through dynamic capabilities and functional competencies:

Hypothesis 3 (H3). *NPD capabilities* (*NPD dynamic capabilities and NPD functional competencies*) mediate *the impact of IT leveraging competence on competitive advantage in NPD*.

5. The Moderating Role of Environmental Turbulence

Environmental turbulence describes the general conditions of uncertainty or unpredictability because of changes in consumer preferences and technology developments (Mendelson and Pillai 1998). Environmental turbulence in NPD arises from two primary sources (Jap 2001): First, market turbulence creates unpredictability in market demands, consumer needs, and competitor strategies. Second, technological turbulence creates uncertainty regarding new technological breakthroughs.

5.1. Environmental Turbulence on IT Leveraging Competence—Dynamic Capabilities Link

In turbulent environments, where there is need for efficient and effective management of knowledge (Grant 1996), the effect of IT leveraging competence on dynamic capabilities is likely to be more pronounced. Environmental turbulence increases the knowledge intensity of business processes, escalating the importance and emphasis on knowledge (Hitt et al. 1998). The increased knowledge intensity of the competitive landscape requires the effective use of IT functionality to support business processes. Because turbulent environments require the use of IT to support rapid communications, the higher the rate of environmental turbulence, the greater the need for IT leveraging competence to support knowledge flows (Mendelson and Pillai 1998). In sum, these suggest that IT leveraging competence in NPD should have a stronger effect on dynamic capabilities in higher degrees of environmental turbulence.

Hypothesis 4 (H4). *The positive relationship between IT leveraging competence in NPD and dynamic capabilities is* positively *moderated* (*reinforced*) *by environmental turbulence*.

5.2. Environmental Turbulence on NPD Capabilities—Competitive Advantage Link

Environmental turbulence is proposed to moderate the NPD capabilities–competitive advantage relationship because it enhances the relative advantage of

reconfiguring NPD functional competencies while weakening the advantages gained from efficiently exploiting existing ones (Teece et al. 1997). Turbulent environments increase the possibility that dynamic capabilities would reconfigure new NPD functional competencies. Dynamic capabilities can be viewed as strategic options (Kogut and Zander 1996), which give a firm the choice to pursue new directions when the opportunities arise. The higher the environmental turbulence, the more likely these options will become valuable (Sambamurthy et al. 2003). In contrast, stable environments reward the efficient exploitation of existing functional competencies (Leonard-Barton 1992). Because NPD functional competencies necessitate a costly, time-consuming, and often irreversible accumulation of resources, their continuous reconfiguration is likely to disrupt their efficiency and value potential (Zammuto 1988). Hence, environmental turbulence reduces the value of existing NPD functional competencies, while it enhances the value potential of dynamic capabilities.

Hypothesis 5A (H5A). *The relationship between NPD functional competencies and competitive advantage in NPD is* negatively *moderated* (*attenuated*) *by environmental turbulence*.

Hypothesis 5B (H5B). *The relationship between dynamic capabilities and functional competencies in NPD is* positively *moderated* (*reinforced*) *by environmental turbulence*.

6. Research Methodology

6.1. Measurement Development

Wherever possible, measurement items were adapted from existing scales. For new measures and for those that required significant changes, standard scale development procedures were used (Churchill 1979). First, the domain of each construct was specified. Second, a large pool of items was developed based on the conceptual definition, ensuring that these items tapped the construct's domain. From this pool, items were chosen based on whether they conveyed different yet related shades of meaning (Churchill 1979). Third, the items were refined based on pretests of the survey instrument. Special care was taken to ensure that the measures were applicable to NPD managers, while capturing their abstract concept. All measurement items were measured at the NPD work unit level, as shown in the appendix. As is common in strategy research, the survey instructions asked the NPD managers to respond relative to their work unit's major competitors.

6.1.1. IT Leveraging Competence in NPD. A new measure was developed for IT leveraging competence in NPD that aimed to assess the extent to which generic IT functionalities are effectively used by NPD work units. Our goal was to assess comparative competence across NPD work units in leveraging general-purpose IT tools with similar functionalities across software packages. However, since some of the NPD activities that are supposed to be enhanced by the IT tools potentially can be performed without the use of NPD packages, our challenge was to specifically capture the effectiveness in using particular IT functionalities to facilitate NPD activities. Hence, the construct's measurement items were introduced with the following request: "Please rate the effectiveness by which your NPD work unit uses the following IT functionalities in the NPD process." To emphasize the effectiveness in leveraging IT functionalities, some items focused on the adequacy of specific IT functionalities, assuming that users who are familiar with these IT tools would report in terms of how well they leverage the functionality to undertake their activities, and not how good the IT tool is. Nonetheless, the NPD activities were underlined to stress to the respondents that the emphasis is on the actual execution of specific activities by effectively using IT functionalities, and not on the quality of the IT tool itself. Moreover, for the NPD activities that could not be undertaken without the use of IT functionalities, the measurement items did not include the particular IT functionality and only assessed the effectiveness in undertaking the particular activity. In sum, we believe that these variations in the phrasing of the measurement items would together capture the IT leveraging competence in NPD construct. Finally, while IT leveraging competence in NPD is supposed to be captured relative to the competition, since it is difficult for NPD work units to self-assess how well they leverage IT tools compared to their major competitors, the measurement items only assessed the absolute effectiveness in using IT functionalities.

The effective use of PRMS was measured with seven new items based on Rangaswamy and Lilien (1997), focusing on the effective use of scheduling and time management, resource management, and task assignment functionalities to prioritize tasks and keep deliverables on track, analyze and measure work, and represent the availability of people, tasks, and resources. The effective use of KMS was measured with six new items, based on concepts in Alavi and Leidner (2001). These items focused on the effective use of coding and sharing of knowledge, creation of knowledge directories, and knowledge networking functionalities to store, archive, and share project information, create online knowledge communities on new products, and locate relevant expertise. The effective use of CWS was measured with six new items based on ideas in Wheeler et al. (1999). These items concentrated on the effective use of conveyance, presentation, and convergence functionalities to allow NPD work units to simultaneously work together in real time. Finally, for validation purposes, we measured the overall degree of IT leveraging competence in NPD with two direct indicator items.

6.1.2. Competitive Advantage in NPD. Following Ray et al. (2004), competitive advantage in NPD is captured at the process level as the outcome of NPD work units. In NPD, competitive advantage can be achieved by concurrently achieving process efficiency and product effectiveness. Process efficiency refers to time to market and development cost, and it was measured with three items (Kusunoki et al. 1998). Product effectiveness refers to product quality and innovativeness, measured with three items (Sethi et al. 2001). Competitive advantage in NPD is thus operationalized as the combination between process efficiency and product effectiveness as a nine-item interaction measure. This operationalization has one degree of separation from the self-reported measures of process efficiency and product effectiveness, thus ex ante helping mitigate concerns about common method bias.

For validation purposes, a direct perceptual measure of competitive advantage was also captured with two items (Jap 2001). Also, three accounting measures—return on sales (ROS), return on assets (ROA), and sales growth (SG)—were reported by the NPD managers at the NPD work unit level as absolute three-year average values (Atuahene-Gima and Li 2004).

6.1.3. NPD Functional Competencies. Marketing and technical NPD competencies were measured using items developed by Song and Parry (1997), while managerial competence was measured with items developed by Sethi et al. (2001). Overall NPD functional competence was also measured with two indicator items.

6.1.4. NPD Dynamic Capabilities. Dynamic capabilities were measured with 37 items (Pavlou and El Sawy 2006). Market orientation was measured with eight items to capture the effective generation, dissemination, and responsiveness to market intelligence by NPD work units (Jaworski and Kohli 1993). Absorptive capacity was measured with 10 items to capture the effective acquisition, assimilation, transformation, and exploitation of knowledge by NPD work units (Zahra and George 2002). Coordination capability was measured with eight items to capture the effective resource allocation, task assignment, and activity synchronization by NPD work units (Malone and Crowston 1994). Collective mind and its three elements—contribution, representation, and subordination—were captured with eight items based on Weick and Roberts's (1993) theoretical description. Finally, for validation purposes, two indicator items captured the overall degree of NPD dynamic capabilities.

6.1.5. Environmental Turbulence. Market and technological turbulence was measured using Jaworski and Kohli's (1993) scales that capture the pace of customer and competitor changes and technological breakthroughs. Moreover, an overall environmental turbulence construct was directly measured with two indicator items.

6.1.6. Control Variables. Several NPD factors that have been previously shown to be related to NPD success were measured, so that their effects on competitive advantage in NPD and NPD capabilities are controlled.

- First, *cross-functional integration* is the quality of interaction among different functional areas; it has been shown to influence the success of NPD (Clark and Fujimoto 1991). It was measured using two-item scale developed by Song and Parry (1997).

• Second, *NPD experience* is measured as the work unit's age (Song and Parry 1997).

• Finally, *firm size* (number of employees and firm revenues), *work unit size* (NPD work unit members), and whether the respondents were *senior* versus *mid-level managers* were measured as control variables.

6.2. Survey Administration

A field study was conducted in which data were collected from two samples of respondents using the same data-collection procedure. One group of respondents was drawn from the 554 participants at the 2002 PDMA (Product Development and Management Association) conference (www.pdma.org/2002/). Additional respondents were drawn from the 161 participants of the 2003 Roundtable Management Conference (www.roundtable.com/codev/CoDev2003/CD03_audience.html). Because the study's key respondents were NPD managers, we first eliminated firms not involved with NPD and job titles not closely corresponding to NPD management. The list was also refined by contacting the participants and asking whether they have been involved in NPD projects as NPD managers. The final list contained 386 (PDMA) and 121 (Roundtable Management) participants.

Invitation e-mails were then sent, explaining the study's purpose and requesting participation. The e-mail body assured recipients that the responses would be treated confidentially and that the results would only be reported in aggregate. The respondents were asked to click on the URL link provided in the e-mail message that linked to an online instrument. The respondents were offered as incentive a customized report that summarized the study's results (more than 90% of the respondents requested this report).

The respondents were asked to self-select a specific NPD work unit that they had managed. To avoid social desirability bias, the respondents were asked to select a work unit with which they were most familiar, and not a typical, successful, or failed one.[14] A formal check also assessed the respondents' familiarity with their NPD work units. Using a cut-off point of 4 (4 = anchored at very familiar and 5 = extremely familiar), all respondents (mean = 4.31, STD = 0.84) were deemed sufficiently knowledgeable and all responses were retained. To collect an equal number of intra- and interfirm NPD work units, the respondents were asked to favor selecting external NPD units. As a result, 56% of the responses were on interfirm work units. Finally, to assure a collective response, the survey instructions requested that the NPD managers obtain collective input by consulting with other members of their NPD work units.

In the first sample, of the 386 respondents, 44 could not be contacted, 12 respondents indicated that firm policy forbade their participation, and 15 of the invitees indicated they were not qualified to participate in the study. After two reminders, 121 responses were received (39% response rate). In the second sample, of the 161 participants, 25 were unreachable, and four indicated inability to respond. Following two reminders, 59 responses were obtained (43% response rate). These response rates are higher than most survey studies because (a) personal communication was sought with the participants, (b) the study was endorsed by the conference organizers, (c) the authors participated in the conferences and established personal contacts, and (d) responses through paper questionnaires were also collected during the conferences.

Nonresponse bias was assessed by verifying that early and late respondents did not significantly differ in their demographic characteristics and responses on principal constructs. Early respondents were identified by selecting those that responded in the first two weeks. All t-tests between the means of the two groups showed no significant differences ($p < 0.1$ level).

Because dyadic data from interfirm NPD work units would have been desirable, if the respondents selected an interfirm unit they were asked to provide the contact information of the respective NPD manager from the partner firm. From the 99 interfirm work units, 47 names were received, and 28 matched pairs were obtained (60% response rate). The average absolute differences in paired responses for all constructs were less than 5%, the average correlation between the respondents was 0.63 (range across constructs =

[14] To address social desirability bias, the performance outcomes of all work units were examined. The mean of the performance outcomes was 3.44 on a five-point scale (STD = 0.78), which was in roughly the middle of the scale.

0.17–0.87), and the interrater reliability alpha was 0.71. These results indicate no systematic bias between the informants, and their responses were thus averaged to derive a single score for each interfirm NPD work unit.

7. Data Analysis and Results

Data analysis was conducted with partial least square (PLS), which is a structural equation modeling (SEM) technique that uses a component-based approach to estimation. Because of the large number of variables relative to the sample size and the existence of second-order formative factors and moderating effects, PLS was deemed more appropriate than other SEM techniques such as LISREL and EQS.

7.1. Respondent Characteristics

The majority of the respondents were from the high-tech (14%), manufacturing (12%), medical devices (11%), and consumer goods (8%) industries. Respondents that represented less than 5% of the sample came from the chemical, electronics, and automotive industries, among others. Of the respondents, 80% identified their positions as NPD managers, 10% indicated executive positions, and 10% indicated "others." The NPD purpose was applied research (68%), basic research (23%), and routine engineering (9%). Demographics and descriptive statistics were similar across both samples. Using Chow's (1960) statistic[15] and Wilk's lambda,[16] the results of the two samples were statistically nonseparable and were therefore pooled.

7.2. Measurement Validation

To assess the construct validity of the principal constructs, in addition to reliability testing[17] we formed the second-order formative constructs,[18] and tested whether they are highly correlated with their indicators.

7.2.1. IT Leveraging Competence in NPD. The reliability of the IT leveraging competence in NPD was 0.95, and the reliabilities for the effective use of PRMS, KMS, and CWS were 0.89, 0.89, and 0.91, respectively.[19]

The second-order construct of IT leveraging competence in NPD was formed by calculating the weights (γ_i) of the first-order constructs to the second-order construct (Edwards 2001) using a principal components factor analysis (Diamantopoulos and Winklhofer 2001, p. 270):

$$\begin{aligned}\text{IT Leveraging Competence in NPD} &= \gamma_1 \times \text{Effective Use of PRMS} \\ &+ \gamma_2 \times \text{Effective Use of KMS} \\ &+ \gamma_3 \times \text{Effectuve Use of CWS.}\end{aligned}$$

The impact of all (γ_1) first-order constructs on IT leveraging competence is significant ($p < 0.01$) (Figure 5).

[15] The Chow test determines whether the coefficients in a regression model are the same in separate subsamples.

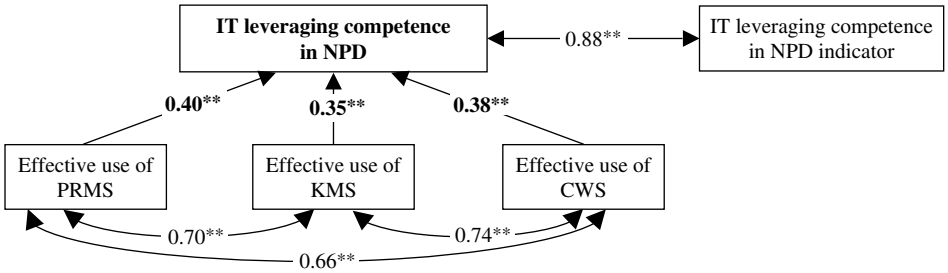
[16] The Wilk's lambda criterion measures differences between groups.

[17] Reliability was assessed with the PLS internal consistency measure.

[18] In PLS, second-order formative constructs can be approximated using two approaches (Chin et al. 2003). The first approach directly measures the higher-order constructs with the measurement items of the first-order factors. The second approach models the path weights from the first- to the second-order constructs (the weights of formative constructs are treated as PLS coefficients, and the variance explained in the second-order construct is unity). The second procedure was chosen since it closely corresponds to our proposed conceptualization of formative second-order constructs.

[19] In addition to reliability testing for all measurement items of each of the first-order dimensions of IT leveraging competence in NPD (effective use of PRMS, KMS, CWS), we compared the correlations among the items that measured effective utilization of IT tools and those that measured the effectiveness of IT tools. For the seven items that measured the effective use of PRMS, the average correlation among all items was 0.69. The average correlation among the four items that measured the effective utilization of IT tools was 0.72, and the average correlation among the three items that measured the effectiveness of IT tools was 0.71. The average correlation among the items that measured the effective utilization of IT tools with the items that measured the effectiveness of IT tools was 0.67. For KMS, the average correlation among all items was 0.70. The average correlation among the four items that measured the effective utilization of IT tools was 0.71, and the average correlation among the three items that measured the effectiveness of IT tools was 0.73. The average correlation among the items that measured the effective utilization of IT tools and the items that measured the effectiveness of IT tools was 0.68. For the effective use of CWS, the average correlation among all six items was 0.74, while the average correlation among the five items that measured the effectiveness of IT tools was 0.75. Because all these correlations are virtually identical, it suggests that the respondents did not respond differently in terms of tool effectiveness and effective tool utilization.

Figure 5 The Second-Order Formative Construct of IT Leveraging Competence in NPD



Note. **Significant at $p < 0.01$.

As shown in Figure 5, the correlation between the two indicator items that measured the overall effectiveness of using IT functionality in NPD with the aggregate second-order construct was 0.88 ($p < 0.001$). Even if the indicator merely serves as a proxy of the second-order constructs, it indicates if the aggregate variable describes what it is intended to measure (construct validity). We also examined the correlations among the first-order constructs, since high correlations suggest that the first-order constructs may belong to the same set, even if formative constructs need not be correlated (Chin 1998). As shown in Figure 5, the correlations among the first-order factors were 0.66, 0.70, and 0.74 ($p < 0.01$). Because a reflective model would render extremely high correlations (often above 0.80), a formative model seems more likely. We also tested whether the second-order construct of IT leveraging competence in NPD fully mediates the impact of the first-order constructs (effective use of PRMS, KMS, CWS) on NPD dynamic capabilities, using a mediation test (omitted for brevity). This step ensures that the second-order construct is a more parsimonious representation of the first-order constructs and fully captures their predictive power on the dependent variable it is theorized to predict (Chin 1998). The IT leveraging competence in NPD measure is the only significant predictor when all first-order constructs are controlled for, confirming its full mediating role. In sum, these tests support the proposed second-order formative model of IT leveraging competence in NPD and verify its construct validity.

7.2.2. Competitive Advantage in NPD. This construct was measured as a nine-item interaction measure between process efficiency and product effectiveness, whose reliability was 0.91. To validate the construct validity of competitive advantage in NPD, we first calculated the correlation betweeen the interaction measure with a direct measure of competitive advantage (Jap 2001). The correlation was 0.67 ($p < 0.01$), validating the proposed measure. Second, we examined the correlations among three accounting measures (ROS, ROA, and SG) with the study's measures. *ROS* is the ratio of net operating income over sales, and is often used as proxy for product quality. *ROS* was highly correlated with product effectiveness (0.68, $p < 0.01$). *ROA* is the ratio of net operating

Table 3 Correlation Matrix and Composite Factor Reliability Scores for Principal Constructs

Construct	Reliability	Mean	STD	ITLC	PRMS	KMS	CWS	DC	FC	CA	ET
IT leveraging competence in NPD (ITLC)+	**0.95**	2.53	1.25	**0.94**							
Effective use of PRMS (PRMS)	**0.89**	2.60	1.14	0.89**	**0.90**						
Effective use of KMS (KMS)	**0.89**	2.63	1.40	0.91**	0.70**	**0.85**					
Effective use of CWS (CWS)	**0.91**	2.45	1.25	0.89**	0.66**	0.74**	**0.79**				
NPD dynamic capabilities (DC)+	**0.92**	3.58	0.82	0.43**	0.26**	0.40**	0.41**	**0.87**			
NPD functional competencies (FC)+	**0.83**	3.33	0.99	0.30**	0.32**	0.25**	0.26**	0.34**	**0.85**		
Competitive advantage in NPD (CA)	**0.91**	14.65	3.75	0.22**	0.26**	0.12	0.20*	0.42**	0.38**	**0.87**	
Environmental turbulence (ET)+	**0.85**	3.28	1.26	0.18*	0.20*	0.15*	0.14	0.22**	0.17*	0.28**	**0.73**

*Significant at $p < 0.05$; **Significant at $p < 0.01$. Items on the diagonal (in bold) represent AVE scores.
+ITLC, DC, FC, and ET are second-order constructs formed by weighted sums of their first-order constructs.

income over average total assets, and is considered a proxy for efficiency. ROA was highly correlated with process efficiency (0.74, $p < 0.01$). *SG* measures the rate of change of sales, and is considered a key indicator of market acceptance of new products. SG was highly correlated with product effectiveness (0.29, $p < 0.01$) and process efficiency (0.34, $p < 0.01$), while it was highly correlated with the interaction measure (0.55, $p < 0.001$). These findings suggest the validity of proposed measure for competitive advantage in NPD.

While the self-reported measure of competitive advantage in NPD can be criticized for its subjectivity, it has its own advantages because archival accounting ratios are not readily available at the NPD work unit level. Nevertheless, to prevent such criticism, we collected archival data for ROS, ROA, and SG at the firm level and matched them with the self-reported accounting ratios at the NPD work unit level. Because the self-reported NPD work unit–level accounting ratios are highly correlated with the corresponding archival firm-level data,[20] this further supports the validity of the proposed interaction measure of competitive advantage in NPD.

7.2.3. NPD Functional Competencies. The second-order model of NPD functional competencies (Figure 2) was obtained by calculating the coefficients of the first-order functional competencies to the second-order factor:

$$\begin{aligned}\text{NPD Functional Competencies} &= 0.33 \times \text{Customer Competence} \\ &\quad + 0.39 \times \text{Technical Competence} \\ &\quad + 0.43 \times \text{Managerial Competence.}\end{aligned}$$

The correlation between the indicator items for overall NPD functional competence with the aggregate second-order construct of NPD functional competencies was 0.84 ($p < 0.01$), and the construct reliability was 0.83. These results suggest the construct validity of NPD functional competencies.

7.2.4. NPD Dynamic Capabilities. Similar tests were performed to assess the formative second-order construct of NPD dynamic capabilities (Figure 3), and the results follow:

$$\begin{aligned}\text{Reconfigurability} &= 0.23 \times \text{Market Orientation} \\ &\quad + 0.33 \times \text{Absorptive Capacity} \\ &\quad + 0.35 \times \text{Coordination Capability} \\ &\quad + 0.27 \times \text{Collective Mind.}\end{aligned}$$

The NPD dynamic capabilities (reconfigurability) indicator was correlated with the second-order construct at 0.81 ($p < 0.00$), while the construct reliability was 0.92, thereby inferring the construct's validity.

7.2.5. Environmental Turbulence. The reliability of the aggregate measure for environmental turbulence was 0.85, which is highly correlated ($r = 0.91$) with its two indicator items, suggesting construct validity.

The reliabilities, descriptive statistics, correlation matrix, and the average variance extracted (AVE) of the principal constructs are shown in Table 3.

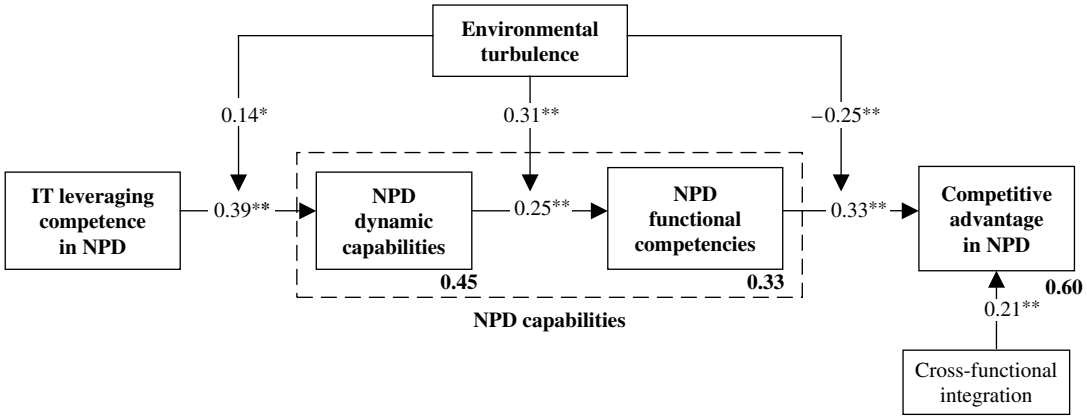
Convergent and discriminant validity is inferred when the measurement load much higher on their own construct than on other constructs, and when the square root of the AVE is larger than the correlations with other constructs (Chin 1998). As shown in Table 3, all AVEs were above 0.70, and they are much larger than all cross-correlations. Moreover, discriminant and convergent validity was also examined using the confirmatory factor analysis procedure in PLS (omitted for brevity). All items loaded heavily on their hypothesized constructs (all above 0.68) compared to all other cross-loadings (all below 0.43). These results suggest that the principal constructs have convergent and discriminant validity.

7.3. Testing the Proposed Research Model

The proposed research model was tested with PLS Graph 3.0. The PLS path coefficients are shown in Figure 6, and the significance levels were assessed with

[20] Even if overall firm performance may not be equivalent to the performance of a specific NPD work unit, comparing overall firm performance with NPD work unit performance is a reasonable validation check. This weighted regression test is based on 64 respondents who provided the required information to allow us to collect archival firm performance data. Firm performance was weighted based on the size of the NPD work unit relative to the firm's size (number of employees). The three univariate regression values for the three performance ratios were beta = 0.18 ($p < 0.05$) for ROA, beta = 0.20 ($p < 0.05$) for ROS, and beta = 0.25 ($p < 0.05$) for SG.

Figure 6 The Proposed Research Model



Notes. Variance explained shown in bold.
*Significant at $p < 0.05$.
**Significant at $p < 0.01$.

200 bootstrap runs. The moderating effects of environmental turbulence were tested as part of the overall structural model with interaction terms formed by cross-multiplying all standardized items of each constructs, following the procedure of Chin et al. (2003). Only significant relationships and significant control effects are shown in Figure 6.

First, NPD functional competencies have a significant direct impact on competitive advantage in NPD (beta = 0.33, $p < 0.01$), thereby supporting H1A. Moreover, NPD dynamic capabilities have a significant impact on NPD functional competencies, supporting H1B. Also, IT leveraging competence in NPD has a significant impact on NPD dynamic capabilities (beta = 0.39, $p < 0.01$), thus supporting H2. As hypothesized, there was no significant direct relationship between IT leveraging competence and NPD functional competencies (beta = 0.03, n/s). The direct impact of IT leveraging competence in NPD on competitive advantage was also not significant (beta = 0.07) when NPD dynamic capabilities and NPD functional competencies were included in the model, thereby supporting the mediating role of NPD capabilities, and thereby supporting H3 (also see §7.4).

The impact of IT leveraging competence in NPD on NPD dynamic capabilities is positively moderated by environmental turbulence (beta = 0.14, $p < 0.05$), thus supporting H4. Environmental turbulence attenuates the impact of NPD functional competencies on competitive advantage (beta = −0.25, $p < 0.01$), thus supporting H5A, while it positively moderates the relationship between dynamic capabilities and NPD functional competencies (beta = 0.31, $p < 0.01$), thereby supporting H5A. The tests for the moderated relationships were conducted by following the recommendations of Carte and Russell (2003), assuring that the variance explained due to the moderated effects is significant beyond the main effects. More specifically, f tests comparing the R^2 values between the main and interaction effects were performed (Chin et al. 2003).[21]

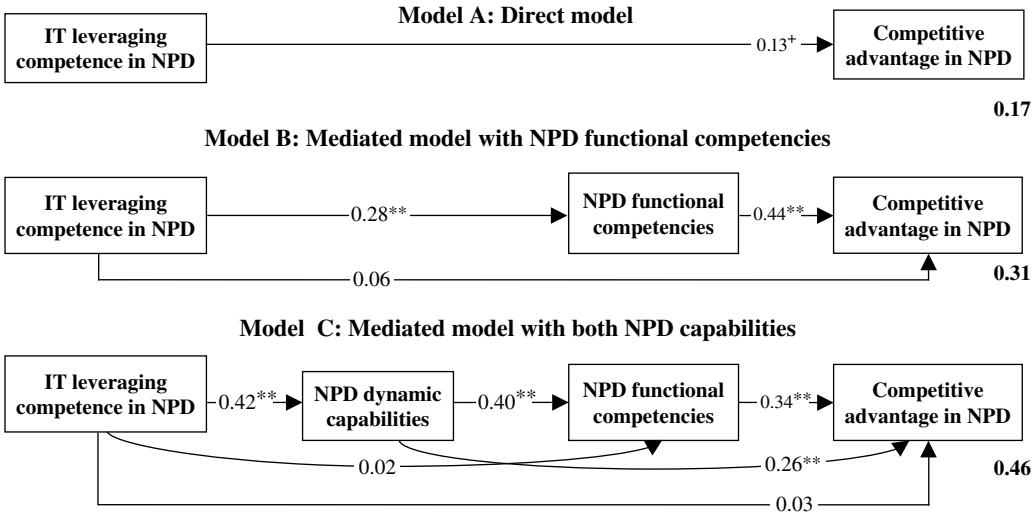
7.4. Further Examining the Mediating Role of NPD Capabilities

NPD capabilities were formally hypothesized (H3) to be a key mediator in the relationship between IT leveraging competence and competitive advantage in NPD. To provide further support for this hypothesis, three models were tested (excluding environmental turbulence).[22] As Figure 7 shows, Model C with

[21] $f = R^2(\textit{interaction model}) - R^2(\textit{main effects model})/[1 - R^2(\textit{main effects model})]$. For the interaction effect between IT leveraging competence and environmental turbulence (H4), $F = 0.15$ that denotes a medium effect. For the interaction effect between dynamic capabilities and NPD functional competencies (H5A), $F = 0.26$, which denotes a large effect. For the effect between functional NPD competencies and environmental turbulence (H5B), $F = 0.18$, which denotes a medium effect.

[22] While Figure 7 shows a significant direct relationship between NPD dynamic capabilities and competitive advantage (beta = 0.26, $p < 0.01$), this coefficient becomes insignificant (beta = 0.11, $p < 0.1$)

Figure 7 Test of the Superiority of the Mediating Role of NPD Capabilities



Notes. Variance explained is shown in bold.
*Significant at $p < 0.05$.
**Significant at $p < 0.01$.
+Significant at $p < 0.10$.

both NPD capabilities explains significantly higher variance in competitive advantage in NPD than either the direct (Model A) or the indirect (Model B) model, the latter of which includes only NPD functional competencies. Therefore, from a predictive perspective, it is necessary to include both NPD capabilities to more accurately predict competitive advantage in NPD.

Notably, Model B suggests that IT leveraging competence in NPD has a significant direct effect on NPD functional competencies. This finding suggests that NPD functional competencies are not IT free, but that the direct effect of IT leveraging competence empirically becomes insignificant when NPD dynamic capabilities are included in the model (as hypothesized in H1B). Finally, as shown in Model C, the direct effects of IT leveraging competence on competitive advantage in NPD are insignificant, thus further validating the full mediating effects of NPD dynamic capabilities and NPD functional competencies.

7.5. The Proposed Research Model at Different Levels of Environmental Turbulence

To examine the proposed model in environments with different levels of environmental turbulence, we formed clusters using the procedure of Ketchen and Shook (1996) that uses Ward's method of hierarchical cluster analysis. The variables used for clustering were market and technological turbulence. The two-cluster solution was selected based on analytical results and a graphic inspection of the icicle plot. As shown in the MANOVA analysis (Table 4), Cluster 1 ($n = 97$) (termed "high-turbulence" cluster) had higher degrees of turbulence than Cluster 2 ($n = 83$) ("low-turbulence" cluster). Most firms in Cluster 1 came from the high-tech, electronics, and telecom industries. Cluster 2 mostly included chemical, manufacturing, and food industries. These distinctions are consistent with Mendelson and Pillai's (1998) high versus low clockspeed industries.

To validate the proposed two-cluster solution (Ketchen and Shook 1996), a second MANOVA analysis

Table 4 Cluster Analysis Results and Cluster Validation

Variable	Cluster 1 ($n = 97$)	Cluster 2 ($n = 83$)	t-value	Comparison
Market turbulence	4.0 (0.95)	2.6 (0.90)	6.12 ($p < 0.01$)	1 > 2
Technological turbulence	4.2 (0.83)	2.3 (0.84)	7.89 ($p < 0.01$)	1 > 2
Environmental turbulence	3.7 (0.82)	2.8 (0.92)	4.32 ($p < 0.01$)	1 > 2

when the moderating role of environmental turbulence is included (Figure 6).

was performed with the overall environmental turbulence indicator as the differentiating factor. This validation confirmed a higher degree of turbulence for the high- versus the low-turbulence cluster (Table 4).

The two samples for each cluster (higher and lower environmental turbulence) were separately analyzed with PLS. As shown in Figure 8, the high turbulence cluster confirms the proposed model. Interestingly, the results also support the proposed research model in the lower environmental turbulence cluster.

To test the extent of common method bias, we performed a number of tests: First, we performed Harman's one-factor test by entering all the principal constructs into a principal components factor analysis (Podsakoff and Organ 1986). Evidence for common method bias exists when one construct accounts for much of the covariance among all constructs. Each principal construct explained roughly equal variance (range = 3.8%–6.4%) (omitted for brevity), indicating no excessive common method bias.

Second, a partial correlation method was used, following Podsakoff and Organ (1986). The highest factor from the principal component factor analysis was added to the PLS model as a control variable on all dependent variables. According to Podsakoff and Organ, this factor is assumed to "contain the best approximation of the common method variance if is a general factor on which all variables load" (p. 536). This factor did not produce a significant change in variance explained in any of the three dependent variables, again suggesting no evidence of common method bias.

Third, we employed Lindell and Whitney's (2001) method, which employs a theoretically unrelated construct (termed marker variable) to adjust the correlations among the principal constructs. Because we did not ex ante measure a completely unrelated construct (to economize on survey items), we used a modified test (Pavlou and Gefen 2005) in which an indirect control variable—functional diversity (Sethi et al. 2001)—was instead included. Any high correlation among any of the items of the study's principal constructs and functional diversity would be an indication of common method bias, because functional diversity is weakly related to the study's principal constructs and these correlations should be close to zero. Because the average correlation among the items of functional diversity and those of the principal constructs was $r = 0.06$ (average p-value = 0.85), the marker variable test showed no evidence of common method bias.

Fourth, the correlation matrix (Table 3) did not indicate any exceptionally correlated variables (highest correlation among principal constructs is $r = 0.43$); evidence of common method bias usually results in very high correlations ($r > 0.90$) (Bagozzi et al. 1991).

Finally, the study's ultimate dependent variable was validated with secondary data, which were independently captured from archival data.

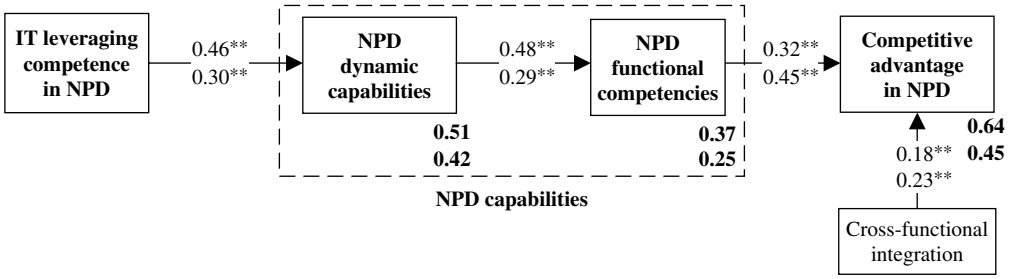
In summary, these five tests suggest that common method bias does not account for the study's results.

8. Discussion

8.1. Key Findings

This study has three key findings. First, it conceptualizes, operationalizes, and measures the construct of IT leveraging competence as a higher-order construct formed by the effective use of IT functionalities (PRMS, KMS, CWS) by NPD work units. Second, it

Figure 8 PLS Results of Proposed Research Model in High- vs. Low-Turbulence Environments



Notes. Variance explained shown in bold. Top number: High turbulence cluster. Bottom number: Low turbulence cluster.
*Significant at $p < 0.05$.
**Significant at $p < 0.01$.

shows that IT leveraging competence in NPD indirectly influences competitive advantage in NPD, an impact that is fully mediated by two types of NPD capabilities (dynamic capabilities and functional competencies). Third, it shows that environmental turbulence reinforces the positive impact of IT leveraging competence on dynamic capabilities. Also, environmental turbulence reinforces the impact of NPD dynamic capabilities on NPD functional competencies, while it attenuates the impact of NPD functional competencies on competitive advantage in NPD.

8.2. Limitations and Suggestions for Future Research

Before discussing the implications of this study's findings, some limitations that create some interesting opportunities for future research must be acknowledged: The use of a single key informant to evaluate the work unit's capabilities and performance suggests that the results may be subject to common method bias. By taking various steps, we tried to minimize the extent of such bias, both ex ante and ex post: Ex ante, by carefully developing the study's measures, we tried to isolate each construct from each other and also from its expected outcomes. Also, the ultimate dependent variable (competitive advantage in NPD) was captured with an interaction variable that was not directly assessed by the respondents, and it was validated with objective archival data. Ex post, we performed multiple tests to examine whether the results were empirically biased. All appropriate checks (i.e., Harman's one-factor test, partial correlation analysis, marker variable analysis, and correlation analysis) empirically confirmed that the results do not suffer from common method bias. Most important, the study's primary contribution is not to simply show high correlations among all constructs. Instead, the primary contribution is to explain how the study's constructs interrelate in a structural model. Common method bias would have instead increased all these interrelationships in a systematic fashion, thus uniformly augmenting all relationships and acting against our hypotheses that NPD capabilities fully mediate the effect of IT leveraging competence in NPD on competitive advantage and that environmental turbulence moderates these relationships in different ways.

The measurement scale for IT leveraging competence in NPD aims to capture the effectiveness by which NPD work units leverage IT functionalities to perform IT-related activities. However, at a first glance, some items appear to capture the effectiveness of the IT tools in general, and not how well they are leveraged. However, the empirical results verified our assumption that these items still tap the IT leveraging competence construct since the correlations among all measurement items were very similar. Presumably, the respondents followed the scale's overall instructions to rate the effectiveness by which their NPD work unit leverages IT functionalities, and they responded similarly for all measurement items. Despite the empirical validation, future research could further refine the measurement of the IT leveraging competence in NPD construct.

The construct of IT leveraging competence in NPD focuses on the leveraging of IT functionalities and excludes the acquisition and deployment dimensions of the original IT capability construct. While this conceptualization may hold well for generic IT technologies (such as those of commercial NPD packages), it may not readily apply to other process-level measures of IT competence where there is substantial variation in terms of acquiring and deploying IT systems. Future research could test the relative impact of IT leveraging competence versus the IT acquisition and deployment dimensions in terms of strategic differentiation. Moreover, future research could develop a multidimensional construct of "IT competence in NPD" by integrating the acquisition and deployment of NPD functionalities under a multidimensional phenomenon.

The IT leveraging competence in NPD construct is based on IT functionalities specifically used for NPD. To enable the study of IT leveraging competence beyond NPD or other specific processes, future research could develop a generalizable measure of IT leveraging competence that is not dependent on context-specific tools.

The proposed IT leveraging competence construct essentially refers to how a standard, undifferentiated set of IT functionalities influences NPD capabilities. Still, some IT functionalities may be more effective than others to support NPD capabilities. Future research could examine whether different IT functionalities may be more effective than others in promoting various organizational capabilities.

Because the proposed construct of IT leveraging competence focuses on the effective use of IT tools, future research could identify the conditions that facilitate the effective use of IT tools at an individual and a collective level, such as training, communities of practice, group incentives, and others.

Because strategic capabilities are difficult to capture with self-reported survey responses, the measures of IT leveraging competence, dynamic capabilities, and functional competencies in NPD may not be perfectly captured with primary data. Future research could use objective third-party assessments for these capabilities.

This study used a process efficiency–product effectiveness interaction variable to measure competitive advantage in NPD, which was highly correlated with a direct perceptual measure and also with three indirect accounting indicators (ROA, ROS, SG). While the level of analysis precluded us from collecting archival data for the NPD work units, the interaction variable and the accounting indicators are an improvement over purely perceptual measures. Nonetheless, the results should be interpreted with caution, and future research could attempt to collect objective performance data at the NPD work unit level.

The study's cross-sectional design did not allow us to observe the longitudinal impact of IT leveraging competence, dynamic capabilities, and NPD functional competencies on sustained competitive advantage. Hence, the results should be treated with caution because causality cannot be inferred with cross-sectional data. While a longitudinal analysis would be a desired approach, solid cross-sectional models must first be established before future research can examine their viability over time.

Finally, we have no reason to believe that the proposed model is not generalizable to other knowledge-intensive processes. Similarly, the process level of analysis could potentially generalize to other firm levels. Future research could examine this model in other contexts and at other levels and units of analysis, and identify potential context-specific contingencies.

8.3. Contributions and Implications for Theory and Research

This study makes three main contributions: (1) the conceptualization and operationalization of the construct of IT leveraging competence in NPD, (2) the indirect impact of IT leveraging competence in NPD on competitive advantage through NPD capabilities, and (3) the moderating role of environmental turbulence. These three contributions and their resulting implications are discussed below.

8.3.1. IT Leveraging Competence in New Product Development. While a burning question in the IS literature is how the IT artifact can be used to build a competitive advantage, the loose use of various general IT-related constructs (e.g., IT investments, IT spending, IT capabilities) may have hindered a consistent understanding of the strategic role of the IT artifact. Also, the firm level of analysis may have obscured the effects of IT on specific firm processes. Finally, the literature has primarily viewed IT capability to arise from within the IT unit. To address these issues, we developed a new process-level construct called IT leveraging competence in NPD. The proposed construct draws on the firm-level IT capability literature, but it takes into consideration the unique characteristics of the NPD process to focus on the leveraging competence of NPD work units (as business users, or clients) outside the IT unit. Because today's NPD packages are generic information technologies whose acquisition and deployment cannot be strategically differentiated, the leveraging of NPD packages is what can provide a differentiable basis for competitive advantage in NPD. The proposed emphasis on the leveraging dimension of IT competence may extend to other processes that use generic ITs whose acquisition and deployment provide minimal basis for strategic differentiation. Finally, whereas the literature on IT capability has focused on the IT unit (e.g., IT managers and staff) as the primary driver of IT capability, this study reveals that IT capability can also arise outside of the IT unit due to the effective leveraging of IT functionalities by business users. This view stresses the human capital development aspect of IT capability beyond IT managers and staff in terms of recruiting and training business users (clients) to effectively use IT functionalities. This finding implies that researchers who only study IT capabilities within the IT unit may be looking too narrowly.

Contrary to other IT-related constructs such as IT investments, spending, resources, and functionalities that may not necessarily have the strategic requirements (rarity, inimitability, and nonsubstitutability)

for building a competitive advantage, we conceptualize IT leveraging competence in NPD as a valuable and rare capability that is hard to imitate. Most important, we show that this construct has strategic implications on competitive advantage in NPD by supporting NPD capabilities. While the strategic potential of IT has been recently questioned (Carr 2003), even for generic IT systems (which can arguably be viewed as commodities), this study implies that the effective leveraging of generic IT functionalities still does matter.

While the IS literature has focused on a high (firm) level view of IS strategy in terms of building an IT infrastructure, managing IT outsourcing, forging IT vendor relationships, and helping chief information officers (CIOs) strategize their firm's overall IT direction, this study argues that a lower (process) level view of IS strategy is also relevant. Consequently, this study implies that researchers who only study IS strategy at the firm level may be overlooking some strategic effects of IT.

While the potential of IT tools to benefit the NPD process has been suggested (McGrath and Iansiti 1998, Rangaswamy and Lilien 1997), NPD still remains an underresearched function in the IS literature (Nambisan 2003). In fact, the IS literature has done little to inform theory and practice as to the potential benefits from using IT tools in NPD, or how specific IT functionalities might be effectively leveraged by NPD work units. By conceptualizing the exact nature of IT leveraging competence in NPD, operationalizing its key dimensions, and showing its impact on competitive advantage in NPD, this study has implications for understanding how NPD work units can leverage IT functionalities to build superior new products.

8.3.2. The Indirect Impact of IT Leveraging Competence on Competitive Advantage. The study's second contribution is to explain the indirect effect of IT leveraging competence in NPD on competitive advantage through the mediating role of NPD capabilities. Specifically, dynamic capabilities and functional competencies in NPD fully mediate the relationship between IT leveraging competence and competitive advantage in NPD. Notably, IT leveraging competence in NPD has an insignificant direct effect on competitive advantage (Figure 7) when both NPD capabilities are omitted from the model. If we failed to account for the role of these NPD capabilities, our results would have shown an insignificant direct impact of IT leveraging competence on competitive advantage, suggesting that the effective use of IT has no strategic potential and adding another controversial finding to the so-called IT productivity paradox. However, by showing the full mediating role of these two key NPD capabilities, this study adds another piece to resolve the infamous IT productivity paradox puzzle.

This study argues that IT leveraging competence should not directly influence competitive advantage, but it should do so indirectly by supporting the effectiveness in undertaking two primary business processes (effectively executing operational processes and effectively reconfiguring existing functional competencies). By viewing the effective leveraging of IT functionality as a distinct capability in its own right, we view IT leveraging competence as a support capability that should have an indirect impact on competitive advantage by enhancing the firm's primary business capabilities. This study describes the process by which IT leveraging competence in NPD influences competitive advantage by suggesting the need for accounting for both dynamic and functional capabilities as necessary mediating links.

By conceptualizing and empirically verifying the role of IT leveraging competence as a direct enabler of dynamic capabilities, this study answers the call for research to better examine how the effective use of IT functionalities can contribute to strategic flexibility, agility, and firm change (e.g., McGrath and Iansiti 1998, Sambamurthy et al. 2003). It suggests that the role of IT leveraging competence may be more prominent in terms of enhancing dynamic capabilities than functional competencies. While more research is needed to fully understand the interrelationships among IT leveraging competence, dynamic capabilities, and functional competencies, this study suggests a sequential link between IT leveraging competence, dynamic capabilities, and functional competencies, at least in the information- and knowledge-intensive context of NPD.

8.3.3. The Moderating Role of Environmental Turbulence. This study also has implications for our

understanding of the role of IT leveraging competence in turbulent environments. The results show that environmental turbulence positively moderates the impact of IT leveraging competence in NPD on NPD capabilities by reinforcing the impact of IT leveraging competence on dynamic capabilities. This finding suggests that the role of IT leveraging competence becomes more pronounced when the environment becomes more turbulent, stressing the notion that the effective use of IT functionalities can have a stronger, albeit indirect, impact on competitive advantage in higher degrees of environmental turbulence. Moreover, the current study implies that the strategic impact of IT capability is more likely to be evident in higher levels of environmental turbulence. Interestingly, the proposed research model holds well even in less turbulent environments. This implies that the beneficial role of IT leveraging competence is important in virtually all levels of environmental turbulence.

8.4. Implications for Practice

For business executives who may be concerned about the strategic potential of their IT investments, this study presents a set of intriguing results: First, even generic IT functionalities outside the IT unit can be a source of differentiation if effectively leveraged by business users. Therefore, managers must also turn their attention to IT training and human development outside the IT unit. Second, the strategic effects of IT are likely to be observed at both the firm's ability to effectively execute operational processes and to effectively reconfigure existing functional competencies. Third, the impact of the effective leveraging of IT systems is more likely to be evidenced in business units that operate in turbulent environments. Managers must thus pay more attention to IT investments for such work units since they are more likely to pay off. These findings inform business executives about the strategic potential of their IT investments, and provide specific steps for enhancing the strategic role of IT.

9. Conclusion

The proposed process-level construct of IT leveraging competence in NPD focuses on the effective use of generic IT functionalities by business users (or clients) outside the IT unit. By demonstrating the strategic potential of effectively using generic IT functionalities by business users, this study aims to entice IS researchers to look outside the IT unit for potential strategic effects of IT. Moreover, the study stresses the leveraging dimension of IT competence, showing that the effective use of generic IT functionalities can still be a source of strategic differentiation. Also, the strategic effects of IT beyond the traditional firm level aim to entice researchers to examine the role of the IT artifact in specific firm processes. Furthermore, by showing that the impact of IT leveraging competence is not directly observed on competitive advantage, this study stresses the need for studying the impact of IT competence on both dynamic capabilities and functional competencies. Finally, the reinforcing role of environmental turbulence on the strategic effects of IT leveraging competence suggests that as environments become more turbulent, the strategic role of IT will become even more prominent.

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Appendix. Measurement Items for Principal Constructs

IT leveraging competence in NPD

Please rate the effectiveness by which your NPD work unit uses the following IT functionalities in the NPD process:

IT leveraging competence in NPD (indicator)
- Overall effectiveness of *using IT functionality* in the NPD process
- Overall adequacy of *utilizing IT tools* in the NPD group

Effective use of PRMS
- Adequacy of IT tools to *visualize and monitor* project status, task lists, and progress of workflows
- Effectively *tracking rapidly changing information* to update project deliverables in real time
- Accurately *providing real-time information on resource availability, usage, and cost*
- Effectiveness of IT tools to *analyze and measure work, tasks, and resources*
- *Quickly prioritizing tasks and keeping deliverables on track* to ensure realistic schedules
- Efficiency of IT tools to *create parallel workflows* so that multiple tasks can be worked on simultaneously
- *Representing the true availability of people, skills, and resources* to enable appropriate task assignment

Effective use of KMS
- Effectiveness of IT tools for *capturing, compiling, and coding relevant information* (product/engineering data)
- Project history (e.g., discussions, insights, work data, documents) *readily accessible for reuse*
- Consistency of IT tools (e.g., databases, content repositories) to *permanently store accurate information over time*
- Leveraging IT tools for *storing, archiving, retrieving, sharing, and reusing* project information and best practices
- Creating *online knowledge communities* (e.g., virtual discussion forums) focused on new ideas and products
- Sufficiency of IT tools (e.g., knowledge networks) for *locating relevant expertise*

Effective use of CWS
- Effectiveness of IT tools to *describe and redefine* product structures, configurations, and routines
- Adequacy of IT tools (e.g., whiteboards, presentation features) to *manipulate the format of contributions*
- Adequately using IT tools (e.g., multithreaded discussions) to *add new meaning to existing knowledge.*
- Effectiveness of IT tools (e.g., transformation functions) to *create meaning to information* by changing its form
- Adequacy of IT tools (e.g., application and desktop sharing) for *simultaneously working together in real time*
- Effectiveness of IT tools (e.g., collaborative design tools) for *seamless virtual product design reviews*

Competitive advantage in NPD

Please rate the performance of your NPD work unit relative to your major competitors in the following aspects:

Process efficiency	Product effectiveness
Overall development costs	Improvements in product quality/functionality
Overall efficiencies of NPD process	Major innovations in products as a whole
Accelerated time-to-market	Creation of new product concepts

Perceived competitive advantage in NPD
- Gain strategic advantages in the marketplace
- Gain a competitive advantage

Accounting ratios
- *Please report the average returns of your NPD work unit during the past three years*:
  - Return on sales (net operating income over sales)
  - Return on assets (net operating income over average total assets)
  - Sales growth (rate of change of sales over the last three years)

NPD functional competencies

Please rate the effectiveness of your NPD work unit in the following activities relative to your major competitors:

Overall NPD functional competence (indicator)
- We do a remarkable job of *developing new products*.
- This product development group *gives us an edge in the market.*

Appendix. (cont'd.)

NPD customer competencies

Frequently *determining market characteristics and trends*
Regularly *appraising competitors and their products*—both existing and potential
Executing several *test-marketing programs* in line with commercialization plans

NPD technical competencies

Evaluating the technical feasibility of developing new products with continuously changing features
Recurrently *evaluating tests* to determine basic performance against *shifting technical specifications*
Frequently executing prototypes or sample product testing

NPD managerial competencies

Management effectively *monitors the progress* of this NPD group
Management *actively involved in activities* at the working level
Management *effectively administers* relevant tasks and functions

NPD dynamic capabilities

Please rate the effectiveness of your NPD work unit in the following activities relative to your major competitors:

Reconfigurability (indicator)

We can successfully *reconfigure our resources* to come up with new productive assets.
We can effectively *integrate and combine existing resources* into "novel" combinations.

Market orientation

We frequently scan the environment to *identify new business opportunities.*
We spend considerable time *reading trade publications and magazines.*
We are quick to *discuss changes in our customers' product preferences.*
We periodically review the likely effect of *changes in our business environment* on customers.
We often *review our product development efforts* to ensure they are in line with what the customers want.
We are effective in *implementing new product ideas.*
We devote a lot of time *implementing ideas for new products* and *improving our existing products.*
We are quick to respond to *significant changes in our competitors' pricing structures.*

Absorptive capacity

We are successful in *learning new things* within this group.
We are effective in *developing new knowledge or insights* that have the potential to influence product development.
We are able to *identify and acquire* internal (e.g., within the group) and external (e.g., market) knowledge.
We have effective routines to *identify, value, and import* new information and knowledge.
We have *adequate routines to analyze* the information and knowledge obtained.
We have adequate routines to *assimilate* new information and knowledge.
We can *successfully integrate* our existing knowledge with the new information and knowledge acquired.
We are effective in transforming existing information into new knowledge.
We can *successfully exploit* internal and external information and knowledge into concrete applications.
We are effective in *utilizing knowledge into new products.*

Coordination capability

We ensure that our work tasks (activities, designs, reports) *fit together very well.*
Overall, our group is *well coordinated.*
We ensure that the output of our work is *synchronized* with the work of others.
We ensure that the output of our work is *of a form useful* to others *when needed* (the right thing at the right time).
We ensure an *appropriate allocation of resources* (e.g., information, time, reports) within our group.
Group members ensure a *fair sharing of resources.*
Group members are *assigned to tasks commensurate* with their task-relevant knowledge and skills.
We ensure that there is compatibility between group members expertise and work processes.

Appendix. (cont'd.)

Collective mind
- We *effectively interrelate our activities* to manage rapidly changing conditions.
- We *collectively manage our tasks* to address situational demands.
- We *promptly make our contributions* to the group with attention and care.
- We are *forthcoming in contributing* our individual input to the group.
- We have a *global understanding* of each other's tasks and responsibilities.
- We are *fully aware* who in the group has specialized skills and knowledge relevant to our work.
- We *carefully interrelate our actions* to each other to meet changing conditions.
- Group members manage to *successfully interconnect* their activities.

Environmental turbulence in NPD

Please evaluate the degree of environmental turbulence that your NPD work unit faces in your product-market area:

Overall environmental turbulence in NPD (indicator)
- The environment in our product area is *continuously changing*.
- Environmental changes in our industry are very *difficult to forecast*.

Technological turbulence
- The technology in this product area is *changing rapidly*.
- *Technological breakthroughs* provide big opportunities in this product area.

Market turbulence
- In our kind of business, *customers' product preferences change* a lot over time.
- *Marketing practices in our product area* are constantly changing.
- *New product introductions* are very frequent in this market.
- There are *many competitors in this market*.

Cross-functional integration
1. There are frequent interactions between our cross-functional NPD group.
2. The NPD process is truly a cross functional effort.

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