Chapter 2
Deriving Business Value from IT Applications in Product Development: A Complementarities-Based Model

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Abstract Many companies that have made considerable investments in IT applications to support their product development activities have realized limited value from such efforts. In this chapter, we argue that a deep understanding of the complementarities that exist in the product development context is critical to ensure that business value is derived from the IT applications. We propose a multi-level complementarities-based model of IT innovation and business value to explain the factors that shape the success of IT-enabled product development. Our model posits that firms will obtain more value from innovative IT investment initiatives when the resulting IT applications are fitted into a system of *initiative or product development context-specific* complementary organizational elements (strategies, structures, processes, etc.). Further, firms will get more value from IT initiatives when investment is combined with certain firm-level elements such as a business strategy that is especially amenable to IT support, strong IT capabilities, and a modern organizational architecture that incorporates a cluster of practices associated with "digital" organizations. The model can guide researchers and managers in identifying the firm-level pre-conditions for realizing value from investments in IT to support product development and specifying necessary complementary investments in organizational change associated with product development.

2.1 Introduction

In recent years, IT applications that support product life cycle management (PLM) have assumed critical importance as companies focus on enhancing the efficiency and effectiveness of their innovation processes across the enterprise. PLM applications provide a common information backbone for all of the company's product development initiatives and also offer connectivity with other business operations through seamless integration with enterprise IT applications such as enterprise

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S. Nambisan (ed.), *Information Technology and Product Development*, Annals of Information Systems 5, DOI 10.1007/978-1-4419-1081-3_2,

resource planning (ERP) and customer relationship management (CRM) (Grieves, 2006; Saaksvuori, 2008).

The promise and the potential of PLM applications to reduce product development cost and time and enhance product quality have led companies to invest heavily in PLM applications. Indeed, the PLM market was approximately $25 billion in 2007 and is expected to grow up to $40 billion by 2012 (CIM, 2008). Despite these large investments in PLM applications, however, few companies have realized the set of benefits that have been predicted. To certain extent, the failure to realize value from PLM applications could be traced to the lack of maturity or quality of the PLM solutions themselves. However, it also points to a larger issue that is plaguing investments in other enterprise IT applications too – the lack of "fit" between the elements of IT and other organizational resources and the resulting disconnect between IT investments and the business value from such investments.

In this chapter, we formalize one important kind of "fit" between IT and organization and inform on the linkages between IT innovation investments and business value by drawing on the *logic of complementarities* (Milgrom & Roberts, 1990, 1995). Specifically, we develop a multi-level, complementarities-based model of IT innovation investments and business value. Our model posits that firms will obtain more value from innovative IT investment initiatives when the resulting IT applications are fitted into a system of *initiative specific* – here, product development context specific – complementary organizational elements (strategies, structures, processes, etc.). In addition, we argue that firms will get more value from IT investment initiatives when they are combined with certain firm-level elements that are not specific to any particular initiative, but rather, complement IT investments more generally construed. These firm-level complements include a business strategy that is especially amenable to IT support, strong IT capabilities, and a modern organizational architecture that incorporates a cluster of practices associated with "digital" organizations (Brynjolfsson, 2003).

The integrated theoretical model of IT innovation investments and business value makes several important and timely contributions. First and foremost, it helps to enhance our understanding of the complementary organizational strategies and practices that would need to accompany the implementation of IT applications (such as PLM) to support product development. Recognition of the broader product development context in which these IT applications are situated also raises several interesting issues for future research in both IT and product development areas.

Second, we use the logic of complementarities to join two important streams of IT research that have proceeded largely in parallel: An *innovation stream* that has examined the determinants of innovative initiatives to adopt and deploy new IT (Fichman, 2000) and a *business value stream* that has examined the contribution of IT investments to organizational performance (Melville, Kraemer, & Gurbaxani 2004). In doing so, we contribute to a better understanding of both firm-level pre-conditions and initiative-level complementary investments that are required to generate business value from IT investments in general.

Finally, investments in IT have increased over the years to the point where IT now represents over half of all capital investments in most companies. Despite increasing evidence that IT investments pay off in aggregate, we still see that IT initiatives produce dramatically varying outcomes from firm to firm, and even from initiative to initiative within a given firm. Our model seeks to account for this variation by using the economic logic of complementarities to analyze why certain clusters of organizational elements should be observed in conjunction with more successful IT investment and deployment. Thus, we contribute to the domain of IT and organizational design by redefining (or, re-conceptualizing) the concept of "fit" between IT and organization and by providing a precise logic for generating eminently testable hypotheses that relate IT to other organizational elements.

The remainder of this chapter is organized as follows. In Section 2.2, we discuss the "disconnect" between the IT innovation investments and the IT business value literatures, and establish the critical need to develop an integrated theory of IT investments, IT innovation, and business value, and the promise of the "complementarities approach" for doing so. In Section 2.3, we review the literature on the logic of complementarities and its application in the innovation and IT literatures. Section 2.4 provides an overview of our research model, and in Sections 2.5 and 2.6, we present the micro-level (i.e., PLM or IT initiative-level) and the macro-level (i.e., firm-level) parts of our model respectively. We conclude the chapter by discussing the important implications of the model for future research and managerial practice.

2.2 IT Investments and Business Value of IT: The Missing Link

The streams of research on IT innovation and IT business value have proceeded largely in parallel. The IT innovation stream has primarily been the province of behavioral science researchers and has addressed two general questions (Cooper & Zmud, 1990; Swanson, 1994): (1) Why are some organizations more prone to exhibit innovative behaviors than others? and (2) Why do some innovations diffuse more widely and rapidly than others? The IT business value stream, on the other hand, has mainly been the province of economics researchers, who have been concerned with establishing whether investments in IT produce business value and under what conditions this value will be greatest (Barua & Mukhopadhyay, 2000; Brynjolfsson & Hitt, 1996; Kohli & Devaraj, 2003; Melville et al., 2004).

The central goal of the IT innovation research stream has been to identify the determinants of IT adoption and implementation. This research has been guided by a number of theoretical perspectives, including the traditional communications-based diffusion of innovation model (Rogers, 2003), adaptive structuration (DeSanctis & Poole, 1994), the technology acceptance model and related approaches (Venkatesh, Morris, Davis, & Davis, 2003), organizational learning (Nambisan & Wang, 2000; Purvis, Sambamurthy, & Zmud, , 2001), network effects (Markus, 1987), institutions (Teo, Wei, & Benbasat, 2003), power and influence (Hart & Saunders, 1997), and mindfulness (Swanson & Ramiller, 2004) to name a few of the more prominent ones. This research has identified scores of different variables that influence organizational innovation with IT – variables pertaining to characteristics of the technologies themselves (e.g., compatibility), characteristics of leaders (e.g., degree of top management support), organizational structural characteristics (e.g., size), characteristics of the workforce (e.g., level of technical knowledge), environmental influences (e.g., competitive pressures), and implementation processes and tactics (e.g., innovation champions) (Fichman, 2000).

While the IT innovation stream has been concerned with whether organizations thoroughly deploy the innovations they have adopted, the ultimate organizational impacts that flow from deployment have been viewed as generally falling outside the scope of this stream, possibly because innovation behaviors are viewed as of intrinsic interest regardless of their specific impacts, or because their impacts are presumed to be generally beneficial (the so-called pro innovation bias), or because of the difficulty of examining both IT deployment and IT impacts within the confines of a single study. Whatever the reason, the absence of work that relates business value to innovation antecedents and behaviors leaves some important questions unanswered, such as how does the extent of deployment relate to business value? Besides the extent of deployment, what conditions at (a) the IT initiative-level and (b) the firm-level affect business value? How can we specify and measure these conditions so as to lead to actionable insights?

One might expect that the natural place to look for answers to the above questions would be the research on the business value of IT. However, with some notable exceptions to be discussed shortly, this research is generally conducted at a level of abstraction and aggregation that precludes answering these specific sorts of questions. Business value research tends to view IT as monolithic: Studies will often link firm-level IT spending or accumulated IT capital stock to firm-level business value (e.g., multi-factor productivity or accounting measures of profits and costs). Such measures of IT investment represent only a partial view of what has actually been spent on IT, and more to the point, do not capture what specific kinds of IT were invested in, when and how the investments occurred, or to what extent such investments can even be viewed as being "innovative."

So, unlike IT innovation research, IT business value research tends not to be contextualized to particular kinds of IT or organizational adopters, and this research does not usually link IT investment and business value to specific innovative behaviors, such as investment timing or extent of deployment. Despite this general stance, there are some notable exceptions. Dos Santos and Peffers (1995) showed that banks that had adopted ATM networks earlier gained a competitive advantage, thus linking an innovation concept (i.e., adoption timing) to business value (i.e., profitability). Hitt, Wu, and Zhou (2001) showed that greater operational improvements occurred for firms that had implemented ERP earlier and more thoroughly. Devaraj and Kohli (2003) linked the extent of IT use in a hospital setting to operational performance improvements. Karimi, Somers, and Bhattacherjee (2007) studied the impact of the extent of ERP implementation (functional scope, geographic scope, organizational scope, etc. of the solution) on business process outcomes (such as process flexibility, process efficiency). Similarly, Mishra, Konana, and Barua (2007) found that the extent of Internet use in procurement order initiation and completion had positive impact on the organization's overall procurement performance.

Despite the just-mentioned empirical work, there is as yet no systematic theoretical model that joins IT innovation and IT business value. Nevertheless, a fair question to ask at this point is why do we need a theory that spans these two domains, and supposing one is needed, why should this integration be based on complementarities? We suggest the following points in answer to these questions.

First, managers need to understand the whole chain of causation from investment to IT deployment and to business value. The bulk of innovation research cannot distinguish instances of IT deployment that produce value from instances that do not. The business value research stream, on the other hand, tends to treat the organization as a black box: IT investment comes in, and business value comes out, but specific causal mechanisms are usually left unspecified. By providing an integrated theory based on complementarities, we not only identify or specify the IT and the organizational design elements that fall inside such a "black box," but also explain how one element or factor "catalyzes" another factor and contributes to the generation of business value. Further, while we do not develop a process perspective of how the IT and the complementary organizational elements come into existence or co-evolve, our specification of an integrated model is a first step in that direction.

An additional advantage of the complementarities approach is that it provides a broad, but still, manageable theoretical scope and allows a clear specification of the model's theoretical boundaries. More importantly, the complementarities approach suggests that many of the same variables affect both IT innovation and IT business value, thus resulting in a true theoretical integration, rather than a "bolting together" of a model of innovation with a model of business value.

2.3 The Logic of Complementarities

Complementarities exist when doing more of one thing increases the returns to doing more of another. Thus, complementarities refer to a synergy between two variables as they impact a third variable. In a landmark paper that formalizes some key mathematical foundations of complementarities, Milgrom and Roberts (1990) provide an extended example of complementarities in action using a stylized description of computer-aided design (CAD). They recount how CAD has automatic links to programmable manufacturing equipment, and hence increases the returns to use of such equipment. CAD also makes it easier to update products more frequently and thereby encourages a broader product line. This, in turn, encourages shorter production runs, lower inventories, and a switch to more flexible manufacturing equipment that is cheaper to change over. They sum up their argument like so: "Thus CAD equipment, flexible manufacturing technologies, shorter production runs, lower inventories, increased data communication, and more frequent product redesigns are complementary" (1990). However, the complementarities are not limited to manufacturing, but spill over into marketing (e.g., faster delivery cycles and a higher emphasis on quality are encouraged) and engineering (e.g., design-for-manufacturability is encouraged).

Given the enormity of the potential benefits extending across multiple functions and indeed the entire enterprise, one might expect that manufacturing firms would have been especially quick to adopt and deploy this technology. However, the actual history of CAD adoption followed a much different story line. The technology was indeed rapidly acquired by manufacturing firms, but many years elapsed before it was actually utilized in a way consistent with the vision of the technology's designers. Liker et al. report that as late as in 1992, a decade after CAD was introduced, "true CAD/CAM [utilization was] still quite rare" (Liker, Fleischer, & Arnsdorf, 1992).

A variety of explanations could account for the slow deployment of CAD, such as technological immaturity, the difficulty of organizational learning, and incentive conflicts. However, the logic of complementarities itself provides an additional compelling explanation: If the majority of CAD's benefits only arise when the technology is combined into a complementary system of elements, this fact would actually serve to *magnify* the ill-effects of technological immaturity, learning barriers, local incentive conflicts, etc. An immature technology tends to have "bugs" (features that are missing, underdeveloped, or just do not work as they should). If benefits are not materializing, how does an organization sort out which problems are due to "bugs" in the technology, or "bugs" in the design of the surrounding organization? If the technology itself is hard to understand due to knowledge barriers, it will be that much more difficult to anticipate the best configuration of complementary organizational elements to build around it. If the technology poses incentive conflicts, that will make it more difficult to rally the whole organization around the need to make complementary organizational changes. Thus, in what might be seen as a supreme irony, complementarities not only magnify the beneficial effects of innovation investment when things go favorably, but may well make it less likely that things will go favorably by magnifying the effects of typical implementation barriers.

2.3.1 Complementarities-Based Studies in Innovation and IT Business Value Research

As the CAD example shows, IT investment entwines with organizational innovation and business value in a manner consistent with the logic of complementarities. Thus, it is not surprising that complementarities have been receiving increasing attention from both innovation scholars and IT business value researchers. In this section, we step back to formalize the logic of complementarities and briefly survey some important empirical work.

According to Milgrom and Roberts, two activities are "Edgeworth" complements if "doing (more of) one thing increases the returns to doing (more of) the others" (1995: 181). A necessary condition for the existence of complementarities is that the effects of two variables (A, B) on a third variable (C) be *supermodular*; that is, the total effects of A and B together must be greater than the sum of the effects of A individually plus B individually. For example, in the CAD case, more investment in and usage of CAD equipment (A) increases the value generating potential of "design-for manufacturability" (B), and vice versa. Thus, value produced from the combination of CAD usage together with design-for manufacturability is greater than the sum of the returns to either taken individually, meaning these two elements are supermodular.

Several alternative statistical approaches have been used to infer the presence of complementarities, including pairwise partial correlations (Colombo & Mosconi, 1995; Hitt & Brynjolfsson, 1997), interaction terms (Bresnahan, Brynjolfsson, & Hitt, 2002; Powell & Dent-Micallef, 1997; Zhu, 2004), and second-order factors (Laursen & Foss, 2003; Tanriverdi & Venkatraman, 2005). Brynjolfsson and Hitt (2003) take a different approach, and infer the presence of complementarities by demonstrating multi-year lags in the arrival of productivity improvements.

In empirical work by organizational innovation researchers, complementarities have been used to explain the linkage between a cluster of a system of "new" human resource practices and greater innovation performance (Laursen & Foss, 2003); the synergy between technological and product market experience in promoting new product development in the pharmaceutical industry (Nerkar & Roberts, 2004); and the effects of business knowledge synergies on performance in multi-business firms (Tanriverdi & Venkatraman, 2005).

Empirical work by IT business value researchers has demonstrated that firm performance is enhanced by combining IT investment with the following complementary sets of elements: flexible culture, strategic planning–IT integration, and strong supplier relationships (Powell & Dent-Micallef, 1997); and decentralization of decision authority, emphasis on subjective incentives, and a greater reliance on skills and human capital (Hitt & Brynjolfsson, 1997). In other notable work, Zhu (2004) found that e-commerce capabilities and IT infrastructure were complementary in their effects on firm-level performance.

Complementarities have also been the subject of theorizing by IT business value researchers. Melville et al. (2004) give a prominent treatment to complementarities in IT business value framework synthesized from a comprehensive review of the literature. In an earlier review of the IT business value literature, Barua and Mukhopadhyay (2000) suggest that complementarities represent the most promising route forward for business value research. They use complementarities to develop a sketch of a theory in which business strategies, IT applications, business processes, and organizational incentives/controls form a complementary system that enhances intermediate firm outcomes (e.g., customer service, time to market, and inventory turnover).

The growing streams of research linking complementarities to innovation and to business value suggest that complementarities hold considerable problem as a foundation for theory that joins both IT innovation and business value. In the following section, we use complementarities to develop a coherent theory of IT investment, innovation, and business value.

2.4 Model Overview: Complementarities, IT Innovation Investments, and Business Value

In this section, we summarize the structure of our complementarities-based model of IT innovation and business value. We also comment on some of the finer points of the model structure and the theoretical assumptions behind it. Then, in the following sections, we give a more detailed explanation of our theoretical constructs and linkages.

Our proposed model operates at two levels of analysis: a *micro-level* that concerns the details of a specific innovative initiative and a *macro-level* that concerns firm-level variables affecting a whole class of IT. We envision four separate chains of causation in the model, labeled A–D in Fig. 2.1. One of these chains operates at the micro-level (A), while the other three (B, C, D) involve macro-level variables.

The micro-level of our model concerns a specific initiative to deploy some emerging IT – for example, PLM to support product development projects, where deployment refers to the breadth and depth of use of the technology itself (see Table 2.1 for suggested measures for IT deployment).

In our first causal chain (link A in Fig. 2.1), we argue that organizations will be better positioned to gain business value from such initiatives when they have coupled the deployment of the technology with a complementary set of initiative-related organizational elements: organizational strategies, structures, processes, policies, skills, and so forth. These initiative-related organizational elements could be pre-existing, co-implemented with the technology, or introduced after implementation.

Many scholars have argued that the scope of "technology" implementation should be expanded to include associated organizational changes (Leonard-Barton, 1988; Orlikowski, 1996). We contribute to this prior work by providing a formal and comprehensive argument relating complementarities to organizational design and change. More specifically, we posit that IT deployment and certain initiative-specific organizational elements will be supermodular, i.e., their combined impacts on business value will be greater than the sum of their individual impacts.

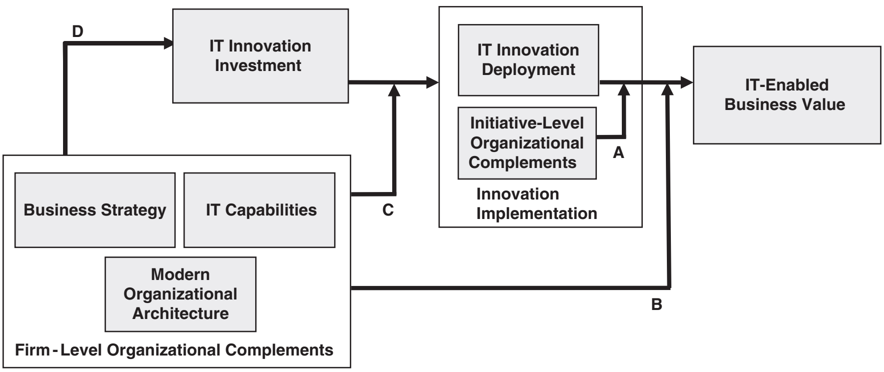

Fig. 2.1 A complementarities-based model of IT innovation and firm value

Table 2.1 Measuring IT investment, deployment, and business value

Construct	Definition	Measures
IT investment	Extent of IT investment has traditionally been defined as actual capital expenditures on IT hardware (and sometimes, also software and/or labor). We depart from this practice and define the extent of investment in terms of timing, commitment, and scope.	We propose three measures for this construct: (a) Investment timing: Organizations that make earlier investments can be viewed as investing more aggressively. Also, early vintages of a technology are generally more complex and less mature, and so cost more to implement. (b) Organizational commitment to deployment: Organizations that are more certain in their intention to deploy a technology can be viewed as more aggressive than those that are less committed. (c) Intended scope of deployment: This captures the intended breadth and depth of deployment. Organizations that aim for a greater scope of deployment can be viewed as making more aggressive investments.
IT innovation deployment	IT innovation deployment refers to the extent to which the IT artifacts comprising the innovation have been implemented throughout the receiving organization in a complete and sophisticated way	We propose two sub-dimensions of IT deployment: Breadth of deployment refers to pervasiveness of technology use in the organization and could be measured as the frequency and extent of technology use across whatever organizational units are most relevant given the nature of the technology (e.g., across people, groups, projects, tasks, and process stages). Depth of deployment refers to the quality of technology use within an organization and could be measured as the number and sophistication of functions in use, the number of inputs/outputs covered by the system, or the variety of information contained with in it.
IT-enabled business value	Business value researchers have divided IT-enabled business value into two broad categories: business process level value and firm-level value. Process level measures are specific to the processes affected by the particular IT in question, while firm-level measures transcend any given process or business function.	Measuring process level value requires that the affected business process be identified. Using new process development (NPD) as an example process, these measures could include the following: Return on investment Reduced NPD cycle time and costs Increased speed of requirements and specification changes Increased NPD project performance Increased new product performance Increased product–market fit Increased number of products, services, or businesses launched in a period Increased percent of revenues from new products in a period Firm-level measures are not specific to a particular business process. Possible measures include the following: Improved relative performance on firm-level accounting profit (e.g., ROA, ROS) or cost (e.g., COGS, SGA). Improved relative growth of sales or market share Increased market value or Tobin's Q

The macro-level of our model pertains to the influence of firm-level variables. As noted in the reviews of empirical research on innovation and business value provided earlier, several organizational elements have been found to complement innovation and IT investment in general. Variables that enhance the effects of IT "in general" would also tend to enhance the effects of IT "in particular" unless there is reason to believe the focal IT is in some way unusual.

In our model, we organize these elements into three categories pertaining to strategy, IT capabilities, and organizational architecture. While prior work has empirically linked many of these firm-level complements to either innovation or IT business value, our contribution is to combine them in an integrated model with well-specified chains of causation. In particular, we posit two different causal chains linking firm-level variables to IT business value, designated by letters B and C in Fig. 2.1.

In the causal chain B, we posit that certain firm-level elements will increase the returns to any given level of IT deployment. For example, when a technology complements the firm's overall strategy, returns from deployment will be higher than when it does not. As a separate causal chain (link C in Fig. 2.1), we argue that these firm-level elements will actually promote more successful innovation deployment through complementarities with the level of IT investment. For example, firms with greater IT capabilities should be better able to plan and manage complex implementations of any given scope. Thus, according to this line of thinking, IT capabilities will magnify the level of IT deployment produced from any given level of IT investment.

As a final causal mechanism (link D in Fig. 2.1), we posit that firms will recognize (explicitly or implicitly) when they hold complementary positions on firm-level elements and will therefore be generally more aggressive when it comes to investing in emerging IT. This does not mean they will necessarily spend more on any given investment initiative. In fact, we can expect that firms that are well positioned (e.g., have strong IT capabilities) will generally have to spend less to achieve any given level IT deployment and business value. Furthermore, other things being equal, deployments that go smoothly should cost less than those that go badly, and ones that go smoothly should produce more business value. As a result, we depart from the traditional practice in IT business value research and suggest that the level of IT investment be measured using variables such as the timing of investment, extent of commitment to deployment, and the intended scope of deployment (see Table 2.1). These measures avoid the paradoxes just mentioned and also have strong linkages with the sorts of innovative behaviors examined in the IT innovation stream.

To wrap up our model overview we discuss three caveats. First, the scope of our model has been intentionally constrained by our interest in complementarities. Therefore, we focus on variables that are plausibly involved in complementary relationships with IT innovation or business value, and even with regard to those variables, we focus on interaction effects consistent with complementarities and give less attention to direct effects. Of course, there are many other variables that potentially affect IT innovation or business directly (as noted in the survey articles cited earlier), but these variables are specifically excluded from the scope of our model.

Second, for each higher-order factor in our model we suggest a representative typology of its potential sub-factors. Our suggestions are not meant to be the only or the "best" typology for each factor, rather just a typology that is representative enough to support more concrete theoretical arguments.

As a third and final caveat, our use of the economic logic of complementarities should not be taken to imply that we have adopted a pure rational-choice perspective on organizational decision making. Our model only requires that when certain organizational elements are present, innovation deployment and business value will be enhanced due to complementarities. While our model does not specify any particular mechanism for how these elements come to be present, we briefly comment on a few possibilities. One mechanism could be an explicit rational-choice process of considering the firm's strategy, IT capabilities, etc., as exemplified in implementation methodologies such as the matrix of change (Brynjolfsson, Renshaw, & Van Alstyne, 1997).

Alternatively, organizational behavior that resembles a rational-choice process could result from implicit assumptions and routines that determine an organization's general innovation posture (more aggressive and less aggressive) toward IT innovation. These implicit assumptions and routines should be more likely in organizations with favorable positions on organizational complements. As a third possibility, it could be assumed that most organizations do little in the way of preplanning, but rather, obtain a fit between technology and organization through cycles of adaptation and learning (Leonard-Barton, 1988). Even so, organizations whose cycles bring them to more favorable systems of complements will be more likely to sustain deployment and will be more likely to gain business value from any given level of deployment. Those that do not will be more likely to have low levels of deployment and business value.

So, our model does not require rational choice. However, there are reasons to believe that a rational-choice process is more likely to maximize business value. A key point made by Milgrom and Roberts (1995) is that partial systems of complements can be sub-optimal or even dysfunctional, and so there is no guarantee that an organization will evolve in an unguided fashion to the best or even a good configuration of complements.

With these caveats out of the way, we now proceed with a detailed development of our model. We begin with the micro-level of the model, and then proceed to the macro-level.

2.5 The Micro-level of the Model: Initiative-Specific Organizational Complements

The micro-level of our model specifies that organizations will obtain greater business value from innovative IT when technology deployment is joined with complementary positions on related organizational elements, including strategies, structures, processes. Unlike the macro-level of the model to be described in Section 2.6, the micro-level must be contextualized to a particular technology. Here, we will consider the context of PLM applications. As noted previously, PLM seeks to consolidate all the activities across the NPD life cycle (ideation, design, development, engineering, manufacturing process management, service, maintenance, product line growth, and retirement) under a common application umbrella, with a shared repository of product data (Bylinsky, 2004).

2.5.1 Linking IT Deployment and Business Value

In the end, IT can only provide business value based on how – and, how much – it is actually deployed. Despite this fact, comparatively few studies of IT business value have actually incorporated IT use:

> Perhaps one of the most serious issues [pertaining to studies of IT business value] has been that few studies have captured the actual usage of the IT. In addition, merely examining the dollars invested in IT may not be an accurate reflection of the effectiveness of IT because the extent of its usage may vary across industries, firms, or processes. Thus, there is a void in the IT payoff literature in evaluating the impact of individual technology usage on organizational performance. (Devaraj & Kohli, 2003, p. 27)

However, there are exceptions. Devaraj and Kohli (2003) consider the direct effects of IT use on performance, as does Hitt et al. (2001). Also, some work by innovation researchers has posited direct links from innovation to organizational performance (Dos Santos & Peffers 1995; Karimi et al., 2007; Mishra et al., 2007; Ramamurthy, Premkumar, & Crum, 1999; Subramanian & Nilakanta, 1996). While we do not doubt that these direct links are extremely important, we are more interested in specifying how the presence of complementary, initiative-specific organizational elements magnifies the value producing potential of any given level of IT deployment.

2.5.2 Complementarities Between Organizational Elements and IT Deployment

> The full advantages of [information] technologies cannot simply be purchased off the shelf; they are won by patiently and carefully tailoring the technology to fit a given firm's organizational and strategic context. At the same time, organizational skills, procedures, and assumptions within the firm need to be adapted to fit the new technology. (Tyre & Orlikowski, 1993, p. 13)

The idea that technology and organization must be fitted to each another in some fashion is a consistent theme that can be seen in such diverse perspectives on technology implementation as socio-technical design (Lyytinen & Mathiassen, 1998), business process reengineering (Davenport & Short, 1990), structuration (Orlikowski, 1992), and mutual adaptation (Leonard-Barton, 1988). However, despite almost universal agreement on this basic point, considerably less agreement exists on what "fit" actually means and exactly why it is important. Sometimes, the nature of "fit" is simply left unspecified, which limits the ability to make specific predictions or to give managerial guidance. This is where the logic of complementarities provides value: It gives an explicit definition of what *constitutes* fit (complementarities), it gives an explicit test for the *presence* of fit (i.e., supermodularity), and it provides a clear specification for the organizational *impacts* of fit (i.e., magnification of the performance-enhancing potential of IT on some variable related to business value).

So far as we are aware, there is no definitive list of organizational elements that can or should be fit to technology. Therefore, based on our review of the literature, we have developed the following representative set of organizational elements: strategies, structures, culture, processes, practices, policies, knowledge and skills, roles, and incentives. To formalize the link between these elements and business value (link A in Fig. 2.1), we offer the following proposition:

Proposition 1: *The effects of IT innovation deployment on business value will be reinforced by the presence of complementary initiative-specific organizational elements (strategies, structures, culture, processes, practices, policies, knowledge and skills, roles, and incentives).*

As stated, this proposition is essentially tautological because complementarities, by definition, reinforce effects on the focal performance variable. However, the tautology falls away when the general proposition is contextualized to a particular technology, as it must be. This process of contextualization can be accomplished by studying technology artifacts, examining accounts of the technology's nature and goals, meeting with experts, and conducting field studies of actual implementations.

For example, in the case of PLM application, a complementary strategy may relate to product portfolio management (Cooper & Kleinschmidt, 2001). Companies that invest in portfolio-level capabilities may find that their portfolio management processes reinforce the PLM solution and enable better utilization of critical organizational resources and assets across different projects. Similarly, adoption of process maturity models (such as the capability maturity model) could create a proactive environment for product development projects and enable better utilization of data and information sourced through the PLM application. Another complementary strategy relates to product platforms. A product platform strategy (Gawer & Cusumano, 2002; Meyer & Lehnerd, 1997) emphasizes modularity and the sharing of components across multiple products. Such a strategy would complement the data standardization and the cross-project information sharing capabilities achieved through PLM implementation and that, in turn, would likely enhance the value the organization derives from the IT solution.

We can identify four specific features that distinguish the complementarities approach from other theoretical approaches to linking organizational variables to technology implementation. First, complementarities require the specific designation of a *performance* or output variable whose levels increase in the presence of complements. By contrast, it would probably be a misuse of complementarities as an explanation for non-performance related impacts of technology and innovation. Second, the focus in a complementarities analysis is on explaining *synergies* between technology and organization as they relate to performance, rather than the effects of each variable directly on performance. Third, complementarities often involve *symmetry* between two elements, where not only A reinforces the effect of B on C, but B reinforces the effect of A on C. While we focus on how organizational elements reinforce the effects of IT, we can often reverse the argument to explain how IT reinforces the effects of the organizational elements. Finally, complements often come in *systems* (or clusters) of three or more elements, where each element of the system reinforces the returns to every other element in the system.

A careful analysis of the product development context would reveal a number of other complementary initiative-specific organizational elements that could potentially magnify the business value that the organization derives from the deployment of the PLM application. Thus, overall, the above analysis not only demonstrates how initiative-level complements would reinforce the impact of IT deployment on business value, but also shows how through a careful evaluation of the four features of complementarities-style analyses (focus on a performance variables, synergies, symmetry, and systems of variables), we can isolate the complementarities effect from other kinds relationships in such contexts.

2.6 The Macro-level of the Model: Firm-Level Organizational Complements and IT Business Value

The organizational complements we examined in the prior section were specific to a particular type of IT investment initiative. We now move from this micro-level to the macro-level and consider the organizational complements that generalize to an entire class of IT investments rather than a particular type of IT.

We posit three categories of firm-level organizational complements: business strategy, IT capabilities, and organizational architecture. Unlike the micro-level of the model, where complementarities have received less attention, there is considerable prior work that considers complementarities at the macro-level, and our selection of these three categories of variables is based in part on this prior work. We also build on this literature by adding more precision to the consideration of the complementarities effects involving these variables. More importantly, by combining their complementarities effects with regard to IT investment and with regard to IT deployment, we contribute toward a more holistic understanding of the role of firm-level organizational complements in IT innovation and use.

We use a well-known business case to illustrate our arguments, in this instance, Cisco Systems. In so doing, we follow the example of Milgrom and Roberts (1995) who used a reanalysis of the classic Lincoln Electric business case to illustrate the role of complementarities in modern manufacturing.

2.6.1 Cisco Systems

In the mid-1990s, Cisco was facing a crisis: Its existing IT infrastructure was becoming increasingly inadequate in the face of the firm's hypergrowth. In a bold maneuver, Cisco conceived and executed a $15 million ERP implementation in only 9 months that, while not without problems, was a remarkable success compared to most ERP implementations of the day (Austin, Nolan, & Cotteleer, 2002). However, this was just the beginning. In the ensuing 2 years Cisco invested $85 million more toward a more ambitious objective, which was to replace all of Cisco's major systems worldwide with a standard Internet-based architecture, i.e., it "web enabled" all major processes in the firm. This involved making all internal systems available through the company intranet, including executive support systems (EIS), decision support systems (DSS), systems to support communication and distance learning, and systems to support collaboration and workflow (Nolan, 2001). Cisco also web-enabled a set of outward facing systems, including supply chain management, customer self-service, e-commerce, and marketing through the web.

In the wake of this implementation, Cisco did an analysis that attributed over $1 billion in cost savings to the web-enablement initiative as a whole. While most of this savings came from improvements in supply chain performance, considerable savings were also attributed to improved customer service, improved workforce productivity, and efficiencies due to the use of the Internet to support commerce. Beyond cost savings, it can be assumed that Cisco also benefited considerably on the revenue side; by serving as an exemplar for business use of the Internet, they no doubt encouraged other firms to do likewise.

2.6.2 Business Strategy

A long line of research has argued for the need to align business strategy and IT strategy in order to maximize the value of IT investments (Chan, Huff, Barclay, & Copeland, 1997). However, only recently has the logic of complementarities entered into the discussion of the link between business strategy and IT investment. For example, Lee, Barua, and Whinston (2000) develop an analytical model that suggests complementarities between e-commerce and a strategy of mass customization. Dehning, Richardson, and Zmud (2003) rely on the logic of complementarities, in part, to explain why IT investments that enable a strategic transformation should produce greater business value than investments that automate or informate individual processes.

Just as initiative level complements cannot be identified until the model is contextualized to a particular technology, the potential complementarities with firm strategy cannot be identified until the model is contextualized to a particular type of firm. Thus, we use a case example, Cisco Systems, to describe the rationales in support of the following generic propositions:

Proposition 2a: *The effects of IT innovation deployment on business value will be reinforced by complementary business strategies.*

Proposition 2b: *The effects of IT investment on IT innovation deployment will be reinforced by complementary business strategies.*

While we do not require that the *same* business strategy be involved in both Propositions 2a and 2b, it can indeed turn out this way. Cisco's primary strategy was to become the dominant supplier of Internet infrastructure worldwide. Through both internal development and an aggressive program of acquisitions, Cisco sought to assemble a broad product line that would permit "one stop shopping" for business network equipment. This *Internet leadership strategy* reinforces the effects of deployment on business value (Proposition 2a), in that it leads to especially rapid sales growth; this, in turn, allows the benefits of Cisco's web-enabled systems to leverage across a larger scale of business activities. Further, as a more diverse set of acquisitions are made, it also allows Cisco to more tightly integrate the business processes by enforcing the same web-enabled systems throughout the extended enterprise, thereby further enhancing the extent of business value derived from it.

The *Internet leadership strategy* also reinforces the effects of Cisco's web-enablement investment (Proposition 2b), because the deep knowledge of the Internet that Cisco gained in the execution of this strategy can be applied to the task of designing and deploying internal systems based on the Internet. The reinforcing relationships go the other way as well (i.e., the relationship is symmetrical). Deployment of web-enablement facilitates the effects of Cisco's Internet leadership strategy by providing a unique marketing asset: Cisco can demonstrate firsthand the potential benefits of Internet use for business, and thereby encourage Internet adoption and increase the demand for their routers. Because they are the dominant Internet infrastructure provider, they capture most of the benefits of demand increases.

In addition, through their own web-enablement deployment, Cisco engages in a cumulative learning process that can be shared with their customers. Cisco's acquisition of KPMG as a consulting arm can be seen as a means to capture and replicate this learning for the benefit of customers. To the extent that customers are more willing to follow Cisco's example and web-enable their own systems, this will increase the demand for the infrastructure that Cisco sells and thereby enhance their business performance.

2.6.3 IT Capabilities

Several authors have noted IT capabilities as a critical determinant of a firm's "conversion effectiveness," i.e., the ability to translate any given level of investment into business value (Weill, 1992; Markus & Soh 1993; Soh & Markus 1995). In empirical work, Bharadwaj (2000) found that firms with high capabilities performed better than a set of matched firms on various firm-level profit and cost measures. While they relied on a proxy for IT capabilities (i.e., ratings of the most innovative users of IT by Information Week's editors), several typologies have been offered to provide a more systematic measure of what constitutes IT capabilities (Bharadwaj Sambamurthy, & Zmud, 1999; Wade & Hulland, 2004).

For the purpose of this discussion, we adopt the typology proposed by Ross and Beath (1996), who argue that IT capabilities ultimately derive from strong positions on three types of IT assets: human, technical, and relationship. They define IT capability as "the ability to control IT-related costs, deliver systems when needed, and effect business objectives through IT implementations" (p. 31). Ross and Beath define the assets that enable this capability as follows:

- The technology asset refers to shareability of technical platforms and databases. Two distinguishing characteristics of a valuable technology asset are well-defined technology architecture, data, and platform standards.
- The human asset refers to the ability of the IT staff to consistently solve business problems and addresses business opportunities through IT. Three distinguishing features of valuable IT human assets are technical skills, business understanding, and a problem-solving orientation.
- The relationship asset refers to the extent that IT and business unit management share the risk and the responsibility for the effective application of IT in the firm. A valuable relationship asset is distinguished by business partner ownership of IT projects and top management leadership in establishing IT priorities.

At the most abstract level, it is nearly self-evident that firms with stronger IT capabilities would be better able to translate any given level of investment into more thorough IT deployment (suggesting complementarity with IT investment) and would be better able to translate any given level of IT deployment into greater business value (suggesting complementarity with IT deployment). In fact, the three parts of Ross and Beath's definition go to these exact points. Firms that have greater ability to "deliver systems when needed" will, other things equal, be better able to convert IT investment into higher levels of deployment. Firms that are "better able to control costs" and "effect business objectives through IT implementations" will find that any given level of IT deployment will cost less and will be more likely to operate IT in a way that produces business value.

This suggests the following two propositions:

Proposition 3a: *The effects of IT innovation deployment on business value will be reinforced by stronger IT capabilities.*

Proposition 3b: *The effects of IT investment on IT innovation deployment will be reinforced by stronger IT capabilities.*

To further develop the rationales in support of these two propositions, we examine more fine-grained complementarities involving each of the three assets that underlie strong IT capabilities, namely technology, human, and relationship assets. In Table 2.2, we provide a rationale for how each asset reinforces the IT investment $\Rightarrow$ IT deployment relationship and the IT deployment $\Rightarrow$ business value relationship. We illustrate these rationales with examples taken from Cisco Systems, particularly the account of Cisco's ERP implementation (Austin et al., 2002).

Table 2.2 IT capabilities, IT deployment, and business value

Type of IT asset	How the asset reinforces relationships	Examples from the Cisco case
Technology asset	Reinforcement of IT investment ⇒ IT deployment: A robust physical infrastructure can better accommodate a major addition in the form of a major new IT implementation. A poor infrastructure has to be retrofitted first, at additional cost and risk. Reinforcement of IT deployment ⇒ business value: A robust physical infrastructure allows deployed systems to be operated and maintained more cheaply. Users will find it easier to locate and access information contained in the deployed systems, thus enhancing the value of those systems.	Cisco established 100% standardization at each level of their architecture: hardware, operating systems, databases, networking, and most applications. This allowed them unusual speed in rolling out new applications (essentially replacing all applications over a 2 year period) and integrating acquisitions (usually completed in 60–100 days).
Human asset	Reinforcement of IT investment ⇒ IT deployment: Large-scale IT deployment requires considerable knowledge and skills to orchestrate the project successfully. IT staff must not only master the technologies to be implemented (technical skill), but also understand how the technology can be best configured to support the business (business understanding) and to be able to solve the problems that inevitably arise in any major implementation (problem-solving orientation). Reinforcement of IT deployment ⇒ business value: Firms with strong IT human assets will be able to operate and maintain any level of deployed systems more efficiently, thus lowering the costs.	Cisco was able to successfully implement ERP in 9 months and replace most of the rest of their IT infrastructure in 2 years, which gives a clear indication of the strength of their IT human assets. Indications of the skill of the IT staff can be seen in their attention to recruiting top-quality implementation partners, the decision to aggressively control the project scope, and their quick and effective responses to setbacks on the project.
Relationship asset	Reinforcement of IT investment ⇒ IT deployment: Any major IT implementation today requires enthusiastic support and participation from other departments and from senior management. Their participation is required to ensure that the right systems and features are chosen and to mobilize the organization.	

Table 2.2 (continued)

Type of IT asset	How the asset reinforces relationships	Examples from the Cisco case
	Reinforcement of IT deployment ⇒ business value: When strong relations exist there will be free flow of information about how well systems are suiting user needs. In this climate, necessary fixes and improvements are more likely, rather than users suffering along with inadequate systems or avoiding use of systems entirely. Also users are more likely to understand how best to use systems as they are.	During Cisco's ERP implementation they took the unprecedented step of reassigning 80 of their "best and brightest" to work full time on the implementation. CEO Chambers made clear his support for the implementation by including successful completion of the project as one of the corporation's top seven objectives for the year.

As explained in Table 2.2, each of these assets has complementarities with IT investment and deployment. However, they also reinforce one another, suggesting a system of complements. Ross and Beath note that

> [T]he relationship asset is heavily dependent on mutual respect, which means that business partners must view the IT staff as competent (human asset), which is partly dependent on the quality and cost of the existing technology base (technology asset). At the same time, competent IT staff members can develop a strong technology infrastructure only if business partners accept some accountability for IT projects (relationship asset) and top management provides sufficient investment for constant reskilling of the IT staff (human asset). The architecture is valuable only if it supports business needs, as articulated by senior business managers (relationship asset), and is effectively and efficiently managed by competent IT staff (human asset). (Ross & Beath, p. 35)

2.6.4 Modern Organizational Architecture

Organizational architecture refers to a firm's organization of labor and related human resource practices (Hitt & Brynjolfsson, 1997). Considerable prior work has examined the question of how certain aspects of modern organizational architectures might complement technology and innovation (Bresnahan et al., 2002; Brynjolfsson & Hitt, 2003; Hitt & Brynjolfsson, 1997; Laursen & Foss, 2003; Milgrom & Roberts, 1995). In this section, we adopt a typology offered by Brynjolfsson (2003) for a set of practices that comprise the "digital" organization.

This typology, based on decade of empirical studies in this area, identifies a collection of five elements[1] of modern organizational architectures that complement IT

[1] Brynjolfsson's (2003) typology identifies six factors, but for brevity we combine two closely related factors – skilled labor, and an emphasis on recruitment and training, into a single factor.

use: (1) automation of routine tasks, (2) emphasis on the use of skilled labor and an increased emphasis on recruitment and training, (3) decentralization of decision making, (4) increased vertical and lateral information flow, and (5) emphasis on performance-based incentives.

We propose two distinct causal chains linking these elements and business value. In the first chain, we propose that some of these elements reinforce the effects of IT deployment on business value (link B in Fig. 2.1). In the second chain, we propose that these practices also reinforce the effects of IT investment on the level of IT deployment (link C in Fig. 2.1). These proposed causal chains are captured in the following two propositions:

Proposition 4a: *The effects of IT innovation deployment on business value will be reinforced by modern organizational architectures.*

Proposition 4b: *The effects of IT investment on IT innovation deployment will be reinforced by modern organizational architectures.*

Brynjolfsson (2003) gives a nice discussion of how modern organizational architecture reinforces the relationship between IT investment and business value. We expand on that by bringing IT deployment into the analysis. In particular, in Table 2.3 we provide rationales for how these five elements each reinforce the IT deployment ⇒ business value relationship, and in some cases, the IT investment ⇒ IT deployment relationship. We also provide examples, where possible, from the Cisco System case.

2.6.5 Firm-Level Complements as a Driver for IT Investment

A large number of studies have confirmed a strong positive association between the aggregate level of IT investment and realized business value, thus dispelling the myth that IT investments do not pay off (Barua & Mukhopadhyay, 2000).

We posit two explanations for the strong relationship between IT investment and business value. First, as we have been arguing all along, firms often join IT investment with organizational elements (complementary strategies, IT capabilities, and modern organizational architectures) that magnify or reinforce the value of those investments. Payoffs do not result from IT investment per se, but rather from how those investments are combined with other organizational elements.

However, perhaps more importantly, we suggest that firms that are well positioned in terms of organizational complements will be likely to invest more in IT to begin with. That is, we posit that these firm-level organizational complements can also drive the decisions related to IT investments. For example, senior managers will recognize when they have business strategies that have potential synergies with IT use and may formulate or support plans for specific IT investments. Similarly, they will recognize when their IT capabilities are strong and the potential synergies this has with IT use may create environments conductive for IT investment.

Table 2.3 Modern organizational architecture, IT deployment, and business value

Practice	How the practice reinforces relationships	Examples from the Cisco case
Automation of routine tasks	Reinforcement of IT investment ⇒ IT deployment: Routine tasks, which require little human judgment, are particularly suitable for automation, thus reinforcing the link between IT investment and IT deployment. Reinforcement of IT deployment ⇒ business value Automation of routine tasks, when it can be accomplished successfully, provides a very direct route to business value. IT systems are the means by which white-collar work is automated.	Cisco's web-enablement initiative allowed automation of virtually any routine task. This can be seen in how Cisco's architecture supports extensive self-service by both employees and customers. None of this self-service would be possible without automating the underlying tasks.
Highly skilled labor, training, and recruitment	Reinforcement of IT investment ⇒ IT deployment: Modern IT is complex and requires higher skill to understand and implement than prior technologies. This suggests that a more highly skilled labor force will increase the level of deployment achieved for any given level of IT investment. Reinforcement of IT deployment ⇒ business value: Much of modern IT can be seen as a tool to amplify human skill by "informating" processes. The more skill that exists to begin with, the greater the productivity benefits that will accrue from amplifying that skill. Also, IT itself is an important tool to facilitate skill acquisition.	Cisco is a high-technology company with a particularly high ratio of white-collar workers (due to outsourcing of manufacturing). It used its web-enabled architecture to implement a robust world-wide program of distance learning, thus reinforcing the value of its skilled workforce.
More decentralized decision making	Reinforcement of IT deployment ⇒ business value: Decentralized decision making has the advantage of being more responsive, and it allows decisions to take into account local conditions. Modern IT enhances the value of decentralization by moving	Senior Cisco managers are equipped with "digital dashboards" that allow them to monitor key performance indicators at lower levels of the organization. All employees are given a personalized "my Yahoo" page that "pushes"

Table 2.3 (continued)

Practice	How the practice reinforces relationships	Examples from the Cisco case
	knowledge and skill down to line workers that was once the sole preserve of senior managers and by allowing monitoring of decision quality by senior managers.	relevant corporate and industry information to their desktops, including live broadcasts of the CEO's address to Cisco's Quarterly Meeting.
Improved vertical and lateral information flow	Reinforcement of IT deployment ⇒ business value: Increased information flow makes organizations more responsive to changing conditions. IT enables more efficient and effective information flow, thus reinforcing the positive impact of any given level of information flow on business value.	Cisco's web-enabled architecture calls for a one-to-one ratio of networked PCs to employees. The above-mentioned "digital dashboards" and "my Yahoo" pages reinforce information flows up and down the organization. Cisco's online directory, which gets millions of hits per year, promotes vertical and lateral communications.
Strong performance-based incentives	Reinforcement of IT investment ⇒ IT deployment: Workers with performance-based incentives will be more willing to adopt new IT tools that could enhance their performance. Reinforcement of IT deployment ⇒ business value: Performance-based incentives are the optimal motivational tool, but only when based on accurate information about performance. Modern IT automatically captures raw data related to performance as workers use it to perform their jobs. Thus, performance data can be captured more accurately and efficiently.	Cisco uses its web-enabled architecture to track individual performance, to give broad access to performance information, such as sales and customer satisfaction, and to allow employees to measure their performance against company goals. Seventy percent of the employees have a very significant bonus related to annual customer surveys.

Finally, they will also recognize when their organizational architecture includes the kinds of modern elements that support – and are supported by – greater IT use and provide added impetus to IT investment decisions. In short, we argue that the very recognition of complementary organizational elements may shape or drive the decisions regarding IT investments in the firm. This rationale leads to our final set of propositions:

Proposition 5a: *Organizations that have business strategies that possess greater potential complementarities with IT use will have higher levels of IT investment.*

Proposition 5b: *Organizations with strong IT capabilities will have higher levels of IT investment.*

Proposition 5c: *Organizations with a modern organizational architecture will have higher levels of IT investment.*

2.7 Contributions of the Model

In this chapter, we have developed a complementarities-based model of IT innovation investments and business value and illustrated its application in the context of PLM. In so doing, we join two robust streams of research – IT innovation and IT business value – that despite important overlaps, have proceeded largely in parallel. The IT innovation stream explains why firms make innovative investments in IT, and how these investments can be translated into greater deployment; the business value stream explains the conditions under which IT investments and deployment lead to business value.

Our use of complementarities as the unifying logic allows us to do much more than simply join existing models of IT innovation and business value "at the hip" with a simple linear sequence from innovation antecedents to innovation deployment to business value. Rather, our approach focuses on variable interactions and illustrates how many of the same variables that interact to increase the business value flowing from IT deployment also have separate effects that increase the level of IT deployment flowing from any given level of IT investment. Indeed, our model goes even further to explain why some firms are more prone to invest in innovative IT to begin with, a question not empirically examined in the business value literature. At a holistic level, our model provides an explanation of the otherwise puzzling *strength* of the observed correlation between IT investment and business: Firms that are best positioned to derive value from IT due to potential complementarities are most likely to invest more aggressively; then these same potential complementarities, when realized, serve to magnify the ability to translate both investment into deployment and deployment into value. Prior work on IT complementarities and business value has not always been precise about whether complementarities reinforce business value directly, or indirectly by reinforcing IT deployment; we show how they do both.

Another key contribution of our model is that it highlights the *importance of initiative-level complements*. These complements have received comparatively less attention from IT business value researchers owning the tendency to treat IT as a monolith, yet at this level the richness and power of the complementarities for informing managerial practice becomes especially apparent. This level of the model allows us to move beyond generic (though no doubt, still very useful) innovation deployment guidance (e.g., pertaining to the need for top management support, innovation champions, attention to organizational learning) to develop rich, technology-specific prescriptions for practice. For example, the model brings a focus to specific product development strategies and capabilities that complement

PLM applications and indicate how organizations can achieve a genuine synergy between deployment of the technology and the related organizational elements.

A final contribution of our model is that it provides a *fourth perspective* on the nature of the causal relationship between technology and organizational change, beyond the three perspectives (technology imperative, organizational imperative, and emergence perspective) identified in Markus and Robey's (1988) influential article. The complementarities perspective shares with the technology imperative the notion that we should tend to see certain clusters of technology and organizational elements, but rejects the notion that technology deployment has "caused" organizational elements in these clusters any more than the organizational elements have "caused" the technology elements.

Furthermore, complementarities reject the technology imperative notion of certain necessary organizational changes that span all adopters, in that the optimal configuration of organizational elements can vary from organization to organization depending on their history and context. The complementarities approach shares with the organizational imperative the idea that organizations often take a rational approach to implementation planning, but rejects the notion that organizations have complete discretion in how the organization is designed around a technology; in that only complementary design elements will lead to enhanced business value.

Finally, the complementarities perspective shares with the emergent perspective the idea that technology and organization can co-evolve in an emergent fashion, but rejects the notion that this process is necessarily chaotic and unpredictable. Rather, it posits that technology and organization tend to be jointly determined according to the logic of complementarities.

2.8 Implications for Research and Practice

Our model suggests three future lines of research. First, as noted previously the model needs to be *contextualized* and applied to specific instances of emerging IT, using a combination of case study and survey approaches. Our effort has been to illustrate the promise and potential for the model to inform on PLM implementation. Further research would be required to identify all the possible organizational elements that complement the PLM application.

PLM researchers applying our model would contextualize the model by identifying (through a literature search, examination of PLM system features, interviews with experts and early adopters, etc.) those specific strategies, structures, processes, skills, etc., that complement use of PLM at the initiative level, and also the nature of the potential synergies between PLM and overall firm strategies, IT capabilities, and modern organizational architectures. The contextualization process would also involve developing measures of the extent of IT deployment (based on what it actually means to deploy PLM more broadly and deeply) and of business value (based on those aspects of organizational performance that should be most affected by PLM deployment – for example, product development cost, time).

While we believe the model as proposed achieves a nice balance between richness and parsimony as it is, we see some especially promising ways to extend the model. One such extension is to add *non-IT functional capabilities* to the macro-level of the model. This would be particularly appropriate for those emerging IT systems used primarily within a particular functional area. To return to the PLM example, we expect that product development capabilities, broadly defined, will have complementarities with PLM deployment.

Another intriguing extension would be to incorporate the idea of *innovation-path complementarities*. Just as a technology can possess complementarities with organizational features, they can also possess complementarities with other technologies that already exist, or more interestingly, are yet to come. Smith (2004) develops these ideas in an examination of the adoption of "linked technologies," where adoption of a technology in one period has complementarities with technologies introduced later.

The study by Zhu (2004) can be seen as illustrating the structure of innovation-path complementarities. This study demonstrates complementarities between IT infrastructure – operationalized primarily as the installed base of IT equipment – and e-commerce capabilities – measured as the sophistication of firm's website and the degree of integration between the website and the back-end systems. Innovation-path complementarities could exist either because one technology interacts with another on a technical level, or because the *knowledge* gained during implementation of one technology pertains to another.

Returning to the PLM example, we might posit innovation-path complementarities with the prior deployment of related technologies (e.g., CAD/CAM, PDM). We might also posit innovation-path complementarities with the deployment of systems that require similar kinds of implementation strategies and knowledge, such as CRM or ERP. It is worth noting that the kernel of this idea does already reside in our proposed model, in that IT technology assets are posited as a dimension of IT capabilities. However, we see the potential for greater development of this concept, and the opportunity to draw interesting connections between innovation-path complementarities and other innovation concepts, such as absorptive capacity (Zahra & George, 2002) and the real-options perspective on new technology investment (Fichman, 2004).

Our model holds implications for managerial practice. First, our model provides a rationale for investing in IT capabilities that support product development in conjunction with investments in other types of product development capability (for example, development process maturity). Such investments can be particularly difficult to justify based on directly observable benefits, and as such, the insights from our model will likely contribute toward adopting a more holistic IT investment decision-making framework. Further, the often found "symmetry" in complementarities effects also imply the potential contribution of IT deployment toward enhancing the returns from investments in other organizational elements (e.g., product development team management practices). This implies the need for IT managers as well as senior business managers to include such considerations while evaluating innovative IT investment opportunities.

Finally, our model also provides a rationale for a concerted strategic role in IT resource commitments. Milgrom and Roberts (1995) have argued that central strategic direction of fully coordinated moves will be especially valuable in the presence of complementarities because partial configurations are not necessarily complementary and may even be counterproductive. As a result, organizations cannot be expected to automatically evolve toward the optimal configuration of complementary elements.

The research implication is to reinforce the importance of robust planning processes that link IT to strategy and that examine the link between technology and organization during implementation. It also suggests that organizations that do choose to engage in a less directed process of adaptation or even improvisation (Orlikowski, 1996) should take special pains to avoid having the implementation "freeze" (Tyre & Orlikowski, 1994) prematurely, before the optimal configuration of complementary elements has been discovered in situ.

Orlikowski (1996) describes how the use of groupware to support help desk incident reports came to be surrounded by system of changes pertaining to employee roles, employee training, worker evaluation policies, and distribution of work among call specialists. The combined effects of these changes were greater than the sum of their parts, suggesting complementarities.

The implication for managers is to enlarge the scope of technology implementation planning to consider complementarities; to be wary of concluding that a technology has no benefits based on partial configurations; and to continually revisit an implementation for the addition of new complementary elements, rather than seeking to rapidly "freeze" some particular configuration.

References

Austin, R. D., Nolan, R. L., & Cotteleer, M. J. (2002). *Cisco systems, Inc.: Implementing ERP*. Boston: Harvard Business School, Case #9-699-022.

Barua, A., & Mukhopadhyay, T. (2000). Information technology and business performance: Past, present and future. In R. W. Zmud (Ed.), *Framing the domains of IT management: Projecting the future through the past*. Cincinnati, OH: Pinnaflex Educational Resources.

Bharadwaj, A. S. (2000). A resource-based perspective on information technology capability and firm performance: An empirical investigation. *MIS Quarterly, 24*(1), 169–196.

Bharadwaj, A. S., Sambamurthy, V., & Zmud, R. W. (1999). *IT capabilities: Theoretical perspectives and empirical operationalization*. Proceedings of the Twentieth International Conference on Information Systems, Charlotte, NC.

Bresnahan, T., Brynjolfsson, E., & Hitt, L. M. (2002). Information technology, workplace organization, and the demand for skilled labor: Firm-level evidence. *Quarterly Journal of Economics, 117*(1), 339–376.

Brynjolfsson, E. (2003). The IT productivity gap. *Optimize*, 21.

Brynjolfsson, E., & Hitt, L. (1996). Paradox lost? Firm-level evidence on the returns to information systems spending. *Management Science, 42*(4), 541–558.

Brynjolfsson, E., & Hitt, L. M. (2003). Computing Productivity: Firm Level Evidence. *Review of Economics & Statistics, 85*(4), 793–808.

Brynjolfsson, E., Renshaw, A. A., & Van Alstyne, M. (1997). The Matrix of Change. *Sloan Management Review, 38*(2), 22–40.

Bylinsky, G. (2004). Not Your Grandfather′s Assembly Line. *Fortune, 150*(1), 136B–136H.

Chan, Y. E., Huff, S. L., Barclay, D. W., & Copeland, D. G. (1997). Information Systems Research. *Business Strategic Orientation, Information Systems Strategic Orientation, and Strategic Alignment, 8*(2), 125–150.

CIM. 2008. *CIM Data Predicts Strong PLM Market Growth for 2007*.http://parts.ihs.com/news/2008/cimdata-plm-market-growth-2007.htm

Colombo, M. G., & Mosconi, R. (1995). Complementarity and cumulative learning effects in the early diffusion of multiple technologies. *Journal of Industrial Economics, 43*(1), 13–48.

Cooper, R. G., & Kleinschmidt, E. J. (2001). Portfolio management for new product development: Results of an industry practices study. *R&D Management, 31*(4).

Cooper, R. B., & Zmud, R. W. (1990). Information technology implementation research: A technological diffusion approach. *Management Science, 36*(2), 123–139.

Davenport, T. H., & Short, J. E. (1990). The new industrial engineering: information technology and business process redesign. *Sloan Management Review, 31*(4), 11–27.

Dehning, B., Richardson, V. J., & Zmud, R. W. (2003). The value relevance of announcements of transformational information technology investments. *MIS Quarterly, 27*(4), 637–656.

DeSanctis, G., & Poole, M. S. (1994). Capturing the complexity in advanced technology use: Adaptive structuration theory. *Organization Science, 5*(2), 121–147.

Devaraj, S., & Kohli, R. (2003). Performance impacts of information technology: Is actual usage the missing link? *Management Science, 49*(3), 273–289.

Dos Santos, B. L., & Peffers, K. (1995). Rewards to investors in innovative information technology applications: First movers and early followers in ATMs. *Organization Science, 6*(3), 241–259.

Fichman, R. G. (2000). The diffusion and assimilation of information technology innovations. In R. B. Zmud (Ed.), *Framing the domains of IT management: Projecting the future through the past*. Cincinnati, OH: Pinnaflex Educational Resources, Inc.

Fichman, R. G. (2004). Real options and IT platform adoption: Implications for theory and practice. *Information Systems Research, 15*(2), 132–154.

Gawer, A., & Cusumano, M. (2002). *Platform Leadership:* How Intel, Microsoft, and Cisco drive industry innovation. Boston, MA: Harvard Business School Press.

Grieves, M. (2006). *Product lifecycle management: Driving the next generation of lean thinking.* New York: McGraw-Hill.

Hart, P., & Saunders, C. (1997). Power and trust: Critical factors in the adoption and use of electronic data interchange. *Organization Science, 8*(1), 23–42.

Hitt, L. M., & Brynjolfsson, E. (1997). Information technology and internal firm organization: An exploratory analysis. *Journal of Management Information Systems, 14*(2), 81–101.

Hitt, L. M., Wu, D. J., & Zhou, X. (2001). Investment in enterprise resource planning: Business impact and productivity measures. *Journal of Management Information Systems, 19*(1), 71–98.

Karimi, J., Somers T. M., & Bhattacherjee, A. (2007). The impact of ERP implementation on business process outcomes: A factor-based study. *Journal of Management Information Systems, 24*(1), 101–134.

Kohli, R., & Devaraj, S. (2003). Measuring information technology payoff: A meta-analysis of structural variables in firm-level empirical research. *Information Systems Research, 14*(2), 127–145.

Laursen, K., & Foss, N. J. (2003). New human resource management practices, complementarities, and the impact on innovation performance. *Cambridge Journal of Economics, 27*(2), 243–263.

Lee, C.-H. S., Barua, A., & Whinston, A. B. (2000). The complementarity of mass customization and electronic commerce. *Economics of Innovation & New Technology, 9*(2), 81–109.

Leonard-Barton, D. (1988). Implementation as mutual adaptation of technology and organization. *Research Policy, 17*(5), 251–267.

Liker, J. K., Fleischer, M., & Arnsdorf, D. (1992). Fulfilling the promises of CAD. *Sloan Management Review, 33*(3), 74–86.

Lyytinen, K., & Mathiassen, L. (1998). Attention shaping and software risk – a categorical analysis of four classical risk management approaches. *Information Systems Research, 9*(3), 233–255.

Markus, M. L. (1987). Toward a "Critical Mass" Theory of interactive media: Universal access, interdependence and diffusion. *Communications Research, 14*(5), 491–511.
Markus, M. L., & Robey, D. (1988). Information technology and organizational change: Causal structure in theory and research. *Management Science, 34*(5), 583–598.
Markus, M. L., & Soh, C. (1993) Banking on information technology: Converting IT spending into firm performance. In R. Banker, R. Kauffman, & M. A. Mahmood (Eds.), *Strategic information technology management* (pp. 375–403). Harrisburg, PA: Idea Group Publishing.
Melville, N., Kraemer, K., & Gurbaxani, V. (2004). Review: Information technology and organizational performance: An integrative model of IT business value. *MIS Quarterly, 28*, 283–322.
Meyer, M., & Lehnerd, A. P. (1997). *The power of product platforms.* New York: The Free Press.
Milgrom, P., & Roberts, J. (1990). The economics of modern manufacturing: Technology, strategy and organization. *American Economic Review, 80*(3), 511–528.
Milgrom, P., & Roberts, J. (1995). Complementarities and fit: Strategy, structure, and organizational change in manufacturing. *Journal of Accounting & Economics, 19*(2/3), 179–208.
Mishra, A. N., Konana, P., & Barua, A. (2007). Antecedents and consequences of Internet use in procurement: An empirical investigation of U.S. manufacturing firms. *Information Systems Research, 18*(1), 103–120.
Nambisan, S., & Wang, Y. (2000). Web technology adoption and knowledge barriers. *Journal of Organizational Computing & Electronic Commerce, 10*(2), 129–147.
Nerkar, A., & Roberts, P. W. (2004). Technological and product–market experience and the success of new product introductions in the pharmaceutical industry. *Strategic Management Journal, 25*(8/9), 779–799.
Nolan, R. L. (2001). *Cisco systems: Web-enablement*. Boston: Harvard Business School, Case #9-301-056.
Orlikowski, W. J. (1992). The duality of technology: Rethinking the concept of technology in organizations. *Organization Science, 3*(3), 398–427.
Orlikowski, W. J. (1996). Improvising organizational transformation over time: A situated change perspective. *Organization Science, 7*(1), 63–92.
Powell, T. C., & Dent-Micallef, A. (1997). Information technology as competitive advantage: The role of human, business, and technology resources. *Strategic Management Journal, 18*(5), 375–405.
Purvis, R. L., Sambamurthy, V., & Zmud, R. W. (2001). The assimilation of knowledge platforms in organizations: An empirical investigation. *Organization Science, 12*(2), 117–135.
Ramamurthy, K., Premkumar, G., & Crum, M. R. (1999). Organizational and interorganizational determinants of EDI diffusion and organizational performance: A causal model. *Journal of Organizational Computing and Electronic Commerce, 9*(4), 253–285.
Rogers, E. M. (2003). *Diffusion of Innovations* (5th ed.). New York: The Free Press.
Ross, J. W., & Beath, C. M. (1996). Develop long-term competitiveness through IT Assets. *Sloan Management Review, 38*(1), 31–42.
Saaksvuori, A. (2008). *Product lifecycle management* (3rd ed.). NewYork: Springer.
Smith, M. (2004). A model of the linked adoption of complementary technologies. *Economics of Innovation and New Technology, 13*(1), 91–99.
Soh, C., & Markus, M. L. (1995). How IT creates business value: A process theory synthesis. In G. Ariav, C. Beath, J. I. DeGross, R. Hoyer, & C. F. Kemerer (Eds.), *Proceedings of the sixteenth international conference on information systems* (pp. 29–41). Amsterdam: ACM.
Subramanian, A., & Nilakanta, S. (1996). Organizational innovativeness: Exploring the relationship between organizational determinants of innovation, types of innovations, and measures of organizational performance. *Omega-International Journal of Management Science, 24*(6), 631–647.
Swanson, E. B. (1994). Information systems innovations among organizations. *Management Science, 40*(9), 1069–1092.
Swanson, E. B., & Ramiller, N. (2004). Innovating mindfully with information technology. *MIS Quarterly, 28*(4), 553–583.

Tanriverdi, H., & Venkatraman, N. (2005). Knowledge relatedness and the performance of multibusiness firms. *Strategic Management Journal, 26*(2), 97–119.

Teo, H. H., Wei, K. K., & Benbasat, I. (2003). Predicting intention to adopt interorganizational linkages: An institutional perspective. *MIS Quarterly, 27*(1), 31.

Tyre, M. J., & Orlikowski, W. J. (1993). Exploiting opportunities for technological improvement. *Sloan Management Review, 35*(1), 13–26.

Tyre, M. J., & Orlikowski, W. J. (1994). Windows of opportunity: temporal patterns of technological adaptation in organizations. *Organization Science, 5*(1), 98–118.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*(3), 425–478.

Wade, M., & Hulland, J. (2004). Review: the resource-based view and information systems research: review, extension, and suggestions for future research. *MIS Quarterly, 28*(1), 107–142.

Weill, P. (1992) The relationship between investment in information technology and firm performance: A study of the valve manufacturing sector. *Information Systems Research, 3*(4), 307–333.

Zahra, S. A., & George, G. (2002). Absorptive capacity: A review, reconceptualization, and extension. *Academy of Management Review, 27*(2), 185–203.

Zhu, K. (2004). The complementarity of information technology infrastructure and e-commerce capability: A resource-based assessment of their business value. *Journal of Management Information Systems, 21*(1), 167–202.

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Information Technology and Product Development
Nambisan, S. (Ed.)
2009, XIV, 218 p. 16 illus., Softcover
ISBN: 978-1-4419-1080-6