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Trust, integrated information technology and new product success

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Abstract

Purpose – The purpose of this paper is to investigate the combined roles via trust relationships of the two technology cores of the firm: information technology (IT) and R&D and their impact on new product success.
Design/methodology/approach – A model was tested whereby trust and the integrated IT strategy account for a significant amount of the variance in a broad range of new product development (NPD) outcomes for a survey sample of 223 manufacturing firms. Respondents said design practices and quality methods like Six Sigma accounted for a total of over 25 percent of the reports of the most helpful approaches in promoting effective NPD. At the same time their biggest challenges were having a clear strategic direction within which to operate and resolving cost and resource issues which accounted for over a third (34 percent) of barriers to success.
Findings – Respondents reported that a total of over 25 percent of the reports of the most helpful approaches in promoting effective included these quality methods. At the same time their biggest challenges were having a clear strategic direction within which to operate and resolving cost and resource issues which accounted for over a third (34 percent) of barriers to success. High-tech firms were less likely to report integrated IT strategies, but this tended to be counterbalanced by high levels of trust in the IT function and adoption of organizational innovations for execution of strategic intent. Implications for future research and practice are discussed.
Research limitations/implications – Survey methods produce broad results with low response rates in most studies involving R&D and NPD, and this study is no exception.
Practical implications – With the challenge of strategy alignment reported by many of these firms, it seems clear that the top management team cannot afford to leave NPD challenges to engineering teams and NPD programs without guidance and general vision.
Social implications – NPD has become the staple of most manufacturing firms as a way of meeting and beating the competition worldwide. However, trust between functional areas often starts before people are even employed and should begin in training and educational programs.
Originality/value – Designing NPD programs is at the heart of many firms' competitive strategies and the fast learning companies are the winners. Very little is known about the trust relationship between IT and R&D and their combined effects on new product success which we have found to be significant and unexpected in their impacts.

Keywords Information technology, Trust, Organizational innovation, New product success
Paper type Research paper

1. Introduction

Trust has been defined in the literature as "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party"

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(Mayer *et al.*, 1995, p. 712). But the number of applications of the concept, especially when examining innovative settings, has been limited. The literature assumes that trust is integral for innovation and product development, but little systematic testing of this proposition has actually been documented (e.g. Bunduchi, 2013).

In this study, trust is not taken for granted. That is, trust is taken as a challenge to achieve; it is not automatic, even in successful organizations. Trust and its antecedents or consequences involve complex causal processes. Models involving trust and the workplace are not the result of common sense, but nuanced and complex in their theory and empirically supported patterns. In this particular application of the concept of trust in the innovation process, new product success can be unique and only partially predicted by the extant literature antecedents in a variety of organizational contexts (Nooteboom, 2013).

In the present study, we examine the conditions under which trust might benefit new product development (NPD) outcomes by using virtual engineering and R&D teams; this research setting has received limited empirical testing to date (Ebrahim *et al.*, 2009, 2010). We find that trust, along with an "integrated information technology strategy" (how intertwined information technology (IT) is in the strategic aspects of the business, cf. Brews and Tucci, 2007; Kettenger *et al.*, 1994), was both directly and indirectly beneficial to new product success. Although high-tech firms are less likely to report an integrated IT strategy, this tends to be counterbalanced by high levels of trust in the IT function and adoption of organizational innovations for execution of strategic intent.

This paper is organized as follows. First, the concept of trust is explored at its most general level. The concept is then developed and applied to the innovation and R&D management process, as well as to the IT function and its management. Next, specific hypotheses emerge in a summary model from this review and are tested with empirical data from 223 companies with new product offerings. Lastly, implications of the results are discussed.

2. Trust

Trust as a concept has a rich research tradition in the academic literature. Since this general, applied concept has been dealt with extensively elsewhere (Fulmer and Gelfand, 2012; Mayer *et al.*, 1995), an in-depth treatment of the concept will not be repeated here. However, the general definition and its key components are worth presenting as an introduction to trust's application to the technological innovation process. The operating definition of trust adopted here has several key elements, including vulnerability, which suggests expectations about the actions of others not directly monitored or under control (Mayer *et al.*, 1995, p. 712). More recently, Schoorman *et al.* (2007) demonstrated the consistency of this construct and additionally allowed for differences in perception of risk depending upon the power relationship between the parties, which could moderate outcomes by context. This is potentially quite important for the innovation process where uncertainty is the norm.

There is reasonable overlap between the NPD literature that deals with trust and the social capital literature (Bakker *et al.*, 2006), even to the point of definitional similarity. For example, Fredericks (2001) defines trust using the same elements as Mayer *et al.* (1995), which include exchange between vulnerable partners under conditions of risk and interdependence, confidence in ability, and willingness to work together in order to meet objectives. Bidault and Castello (2008) found that there was a limit to trusting relationships in R&D teams' successful outcomes. Further, Clercq *et al.* (2009, p. 283) found: "[…] sample of 232 Canadian-based firms demonstrate that at higher levels of social interaction, the positive relationship between task conflict and innovation is stronger, and so is the negative association between relationship conflict and innovation. Furthermore, at higher levels of trust, the positive association between task conflict and innovation weakens." This suggests that the relationship between trust and R&D performance is quite complex in most organizations. This issue is taken up again in the "Discussion" section later.

The challenge of building and sustaining trust is daunting: about 59 percent of NPD teams exist in disharmony (Fredericks, 2001). This is especially true for NPD teams that are geographically dispersed, consisting of nationally diverse members in which language and cultural barriers may undermine trust (Muethel *et al.*, 2012). Often trust in ability seems to be a common theme, and in the new product context, this often reduces to technical competence (Madhavan and Grover, 1998). It may not be surprising that methods of accomplishing joint development tasks often involve contracts, which have been the subject of the evaluation literature (Willcocks and Choi, 1995). One of these studies found that contracts and trust are not substitutes in repeated exchanges between two firms, and there are contingency planning results from learning how to manage these relationships (Argyres *et al.*, 2007). This is especially important when intellectual property (IP) is involved (Hoecht, 2004), and in the interaction of IT quality with entrepreneurial corporate culture (Bradley *et al.*, 2006).

2.1 IT and trust

The literature on trust and IT has been primarily focused on the general topics of security and privacy (Andriole, 2006; Patton and Josang, 2004), with an occasional visit to supply chain management issues and data quality trust in general (Huberman *et al.*, 2005). In a study of virtual teams, Henttonen and Blomqvist (2005, p. 108) define trust as "an actor's expectation of other actors' capabilities, goodwill, self-reference visible in mutually beneficial behaviour enabling cooperation under risk," which is very similar to the general definition of trust presented above (Mayer *et al.*, 1995).

Managing the virtual enterprise after a merger or acquisition also requires building trust. For example, in the case study reported by Pepper and Larson (2006), lack of trust, culture clash, poor timing, and commitment lead to significant challenges when a high-tech company acquires a smaller firm. The combination of information communication technologies and face-to-face communication are needed to meet these integration challenges.

One central interest here is the research stream in the IT management literature on management of virtual teams. Pursuant to this point is the small but growing literature on IT support of NPD and trust issues (Muethel *et al.*, 2012; Weisenfeld *et al.*, 2001). The latter study found that risks can be shared, and if partners concentrate on their complementary strengths, the high costs of R&D can be reduced by accelerating time to market. However, this is a difficult challenge when applied to the R&D/IT interface, since hardware/software systems are often purchased. For example, Sen and Rubenstein (1989) found that R&D involvement in technology acquisition varies greatly across firms, typically with little involvement in the early stages of projects. Further, they found that maturity, urgency, and importance to the firm are negatively associated with R&D involvement in the acquisition process. R&D capabilities tend to determine involvement across firms (Sen and Rubenstein, 1990).

Trust is more difficult to build at a distance, especially in the global, virtual firm, and often authors reported that a face-to-face meeting at the beginning of an NPD project to plan the effort promotes new product success (Smith and Blanck, 2002; Jarvenpaa *et al.*, 2004). However, the essential roles played by IT and the facilitation of trust-building (Kasper-Fuehrer and Ashkanasy, 2003; Bal and Gundry, 1999), especially in collaborating with external partners (Scott, 2000), are themes that repeat often in the literature intersecting trust and IT management of virtual teams.

Several studies indicate that virtual teams used in NPD are merely extensions of traditional teamwork, which requires trust for high performance (Henttonen and Blomqvist, 2005). Heinz *et al.* (2006) studied 56 R&D projects whereby several organizations cooperate using an electronic system platform. They found that "communication (team trust) is particularly important in the case of a high degree of electronic linkage," and that "enhancement of team spirit is more conductive to success in larger groups […]. [and in] projects with a great degree of task novelty (exploration), trustful communication becomes particularly important" (Heinz *et al.*, 2006, p. 66). Further, if managed correctly, virtual teams can enjoy most of the benefits of face-to-face team collaboration and trust (Gallié and Guichard, 2005). This includes integrating the various IT platforms and communication channels; the latter authors found that integrating the various collaboration technologies available, ranging from post mail to teleconferences, videoconferences, and virtual collaboration, was essential to the performance of scientific teams. Andriole (2006) argues that technology integration supports collaborative business modeling. The first three hypotheses for testing summarize this literature:

H1. The degree to which a firm pursues an integrated IT strategy directly relates to positive NPD outcomes.

In particular, several studies have shown that, especially, when teams are dispersed, IT tools are needed to promote integration (e.g. Aldea *et al.*, 2012; Boutellier *et al.*, 1998). One study (Kleis *et al.*, 2012) found that a 10 percent increase in IT input accounted for 1.7 percent increase in innovation output for given levels of R&D spending. These findings highlight how trust in IT can and does impact innovation performance:

H2. Higher levels of trust in the IT function are directly related to positive NPD outcomes.

Research has shown that trust within and between functions promotes R&D success (e.g. Kyriazis *et al.*, 2012; Dodgson, 1993). This could be due to "cognitive proximity" of cross-functional members (Huber, 2011), and the longer term benefits of trust on information sharing (Park and Lee, 2014):

H3. Higher levels of trust in the IT function promote a higher degree of pursuit of an integrated IT strategy (mediation role of trust).

Several studies have shown how mediation operates in models of project performance. For example, Yang *et al.* (2012, p. 182) found that KM practice adoption fully mediates the IT application on project performance as measured by schedule, cost, and quality. More importantly for this study, interpersonal trust moderates the relationship between knowledge distance and ease of knowledge transfer. Another study found that psychological safety mediates the relationship between relational capital and innovation in R&D teams. Other research found that trust mediates the relationship between processes for obtaining information and promoting creativity (Brattstrom *et al.*, 2012) which is directly reflected in *H3*. Trust has been found to be more important in fostering knowledge exchange in geographically dispersed teams and the trust-effectiveness relationship is moderated by team flexibility, computer-mediated communication, and national diversity (Muethel *et al.*, 2011).

2.2 Trust and the innovation process

Perhaps the best starting point for a discussion of applied research on trust and the innovation process would be the study by Dan Kegan (1971). Kegan used T-group (sensitivity training) interventions in two R&D departments of a large industrial firm in an attempt to increase individuals' feelings of trust toward their own work group and toward others, keeping people aware of the demands of their task. Significant changes over time in self-actualization and focal group trust were found for the field experimental groups but not the control groups selected for comparison. Kegan and Rubenstein (1973) reported that an individual's greater trust in his/her team promotes more interaction and self-actualization while maintaining awareness of the task in groups.

Kegan was one of the first to question the assumption that trust and openness are values that will eventually lead to better performance. In fact, one of the findings of the study was that internal decision makers (e.g. supervisors) often do not reward technical employees who are confrontational and questioning, which tends to lower the scores of some personnel who experience increases in trust. Further, even in this study, which was published over 35 years ago, the value of using experimental groups that experience significant increases in trust as models for the rest of the organization is questioned. Among other things, Kegan notes that sensitivity or confrontational meeting interventions had not been compared with other organizational development methods (at the time) such as community organization and development or labor relations models.

Uncertainty and power can play a significant role in establishing and maintaining trust (Korsgaard *et al.*, 2015). Seeking balance between creativity and effective coordination is often cited in software design studies (e.g. Kappel and Rubenstein, 1999). This is an important consideration given the intensification of stakeholder bargaining power in general (Coff, 1999), and human capital bargaining power in particular (Campbell *et al.*, 2012). In fact, it could be argued that in most firms IT and R&D compete for innovation resources making the technical human capital literature relevant.

Prasad and Rubenstein (1992) studied 45 R&D projects in 23 companies and found that early involvement of marketing project selection focuses efforts on customers and reduces political impact on outcomes, but this same influence if carried into the implementation phase can be dysfunctional. Although not directly relevant to the R&D-IT interface, the relationship between marketing and R&D has long been considered a key determinate of new product success (e.g. Gupta *et al.*, 1986; Moenaert and Souder, 1990; Song and Zhao, 1996; Griffin and Hauser, 1996; Brockhoff and Chakrabarti, 1988). Functional integration attention has turned to the information processing needs of the R&D groups (Keller, 1994) and the role of virtual teams, (Griffith *et al.*, 2003) and is a modern extension of the laboratory communication studies of earlier decades (e.g. Chakrabarti and O'Keefe, 1977).

More recently, Bouty (2000) studied informal exchanges of (proprietary) resources between R&D scientists and found that social capital is a key predictor of this exchange process, under conditions of acquaintance and mutual trust. The rise of research on networks in the innovation process is very much tied to this early result. Although R&D personnel will not exchange this type of information unless they think no economic harm will result to their own companies, this assumption has not been rigorously tested. Bouty interviewed 38 researchers and compiled a net of 118 examples of resource exchange requests. Not all potential exchanges materialize, primarily because of confidentiality constraints imposed by most organizations, but "data indicate that […] scientists do not intend to exchange resources that they consider confidential" (Bouty, 2000, p. 54). These results were more or less replicated by Dahl and Pedersen (2005), who found that more experienced engineers are also more likely to receive valuable information from their networks because of long-term relationships based on trust and reputation, and thus act as conduits for their firms. These findings are extended by the research reported by Ashleigh and Nandhakumar (2007), who studied engineering teams working in two organizations within the energy distribution industry. In total, 13 aspects of trust, which were identified through interviews – within team, between teams, and in technology-focused interviews – were compared for similarities and differences. "Results showed that feelings of trust in terms of confidence, respect, commitment and teamwork were significantly higher within teams than between teams […] and team members working together within the same team are more likely to have developed higher trust through a sense of belonging when they reach this identification stage of trust" (Ashleigh and Nandhakumar, 2007, p. 612).

Chen (2004) found that equity relationships outperform contractual relationships in knowledge transfer performance, and that trust and adjustment (i.e. resolution of incompatibilities) have significant, positive effects on knowledge transfer outcomes. Chen (2004) noted that "opportunistic behavior often leads to an alliance failure" (p. 318). A related study by Mora-Valentin *et al.* (2004) analyzed 800 cooperative agreements between

Spanish firms and research organizations. They found that the success of these agreements varies depending upon whether the unit of analysis is a firm or a research organization. Firm cooperative agreement performance depends upon commitment, previous links, definition of objectives, reputation, and conflict. Research organizations had higher cooperative agreement performance if there are previous links, communication, commitment, and trust (integrity and benevolence). The type of knowledge (explicit vs tacit) moderates these findings, as it did in another study by Santoro and Bierly (2006).

Supporting and extending these findings, MacDonald and Piekkari (2005) studied ESPRIT (the European Commission program of research on IT) and found that formal agreements among collaborating organizations are reinforced by relationships among individual employees, which are, in turn, strengthened by trust. "The rules of the personal information network may not be explicit, but they are strict. Those who do not put information into the network soon lose their entitlement to take information out, and are rapidly ostracized" (MacDonald and Piekkari, 2005, p. 448). In high-tech firms, especially, trust is quite important for promoting knowledge sharing, as reported by Jian *et al.* (2010) and 116 firms and network relationships. Trust promotes new product innovation for inter-organizational projects (Maurer, 2010). Jiang *et al.* (2013) studied 205 partnering firms in China and reported a U-shaped curve for goodwill-trust and knowledge leakage and a negative relationship for competence-trust impact on knowledge leakage. Consistently, it appears, when empirical studies are published, they show a link between trust and NPD organizations (Brattstrom *et al.*, 2012).

Chen (2004) found a curvilinear relationship between conflict among the partners in a technology transfer relationship and performance outcomes (knowledge transfer). That is, when technologies are at stake, low and high levels of conflict are dysfunctional while moderate levels of conflict are optimal. In high-tech firms, the type of knowledge being generated, stored, transferred, and modified is quite different than in other organizations, and this moderates the trust, innovation, and IT relationships (cf. Santoro and Bierly, 2006). Trust is more difficult to build in complex, risky task environments. We posit that this could be exacerbated when virtual teams, supported by new IT, are managing projects. IT and R&D are often in conflict over new technology resources and are at odds over standardization of protocols in information support technology vs innovation and creativity. On the other hand, R&D has a vested interest in influencing IT strategy. If R&D can influence IT support specifications and implementation in a way that customizes collaborative platforms, then there is strong potential to build trust between these two technology cores of the firm (cf. Keller, 1994). If R&D is stressed by the lack of balance between corporate and divisional effort, then conflict often results, restricting the flow of ideas, especially for new products and services with radical changes in technology (Rubenstein *et al.*, 1997).

It may be that the critical characteristic of the information function in the firm is how well it is integrated across the enterprise and aligned with the firm's mission and strategy (Rubenstein, 1964, 1989; Baker *et al.*, 1967; Prasad and Rubenstein, 1992; Geisler and Rubenstein, 1987). For example, Wainwright and Waring (2004) identified four domains of information systems integration: technical, systems, strategic, and organizational domains. It is the latter two that we focus on here since alignment of the IT function with other enterprise functions is the focus of our theory (Chan *et al.*, 1997; Miles *et al.*, 1978) and measurement (Venkatraman and Ramanujam, 1986). Thus, we refer to an integrated IT strategy as how intertwined IT is in the strategic aspects of the business.

Further discussion of integrated IT appears in the methods section to follow, but the literature is clear on the purpose of IT being consistent with the performance goals in most companies – the standardization of information is paramount to IT performance. But as indicated earlier, the technical human capital argument suggests that the IT and R&D

functions compete for human capital resources. Since these two units compete for resources and often work together, coordinating effort, social capital processes are also in play. Muethel *et al.* (2012) found that trust among NPD team members is more important under conditions of global dispersion, virtual teams, and national diversity. This evidence suggests that comparable conditions often exist when NPD teams involve or are coordinated by the two technology functions in the firm: R&D and IT.

The association, both direct and indirect (mediating), between R&D intensity and an integrated IT strategy is examined in the following two-part hypothesis offered for testing:

H4a. R&D intensity has an inverse impact on integrated IT strategy; that is, in the high-tech firm, IT strategy tends to be less integrated than in low-technology firms.

H4b. R&D intensity has a direct association with trust in the IT function (which in turn, promotes an integrated IT strategy). The inverse is also proposed, to be consistent: without trust in IT, high-tech firms are less likely to have an integrated IT strategy.

The rational for the distinction between high-technology and low-technology firms is based in part on results showing that knowledge distance and knowledge complexity are greater in high-technology firms, and these knowledge characteristics moderate the impact of trust on knowledge transfer. As mentioned earlier, trust among co-development partners is especially challenging when IP is due to the risk of knowledge spillovers and competition for resources is prevalent in high-technology projects (e.g. Hoecht, 2004).

High-technology firms, it could be argued, place greater and unique demands on IT support well beyond standardization of information systems, which often operates against new project success. Both dynamism and complexity of high-technology projects underpins the logic of *H4a*. Integrated IT reduces transaction costs and promotes better use of resources (*H4b*). The economic theory of appropriation (e.g. Teece, 2006) predicts that successful innovating firms allocate more resources to strong appropriation projects (i.e. protected by IP) as opposed to weak appropriation projects, such as those outsourced by the IT function, which cannot be protected and appropriated.

Finally, the execution of any strategy, here an integrated IT strategy, is essential to success, and the literature suggests organizational innovations are paramount to this successful execution. For example, Ettlie and Reza (1992) found that four types of organizational innovations in hierarchy and integrating structure are directly and significantly related to a wide range of successful outcomes of implementation of advanced manufacturing technology. Majchrzak *et al.* (2000) reported similar results for implementation of a virtual team in the aerospace industry and a new rocket design. Chae *et al.* (2005) found that cooperation should precede the IT-based inter-organizational linkage effort. That is, synchronous adoption (planned or emergent) of technological and organizational innovation promotes success (Ettlie, 1998). Measures and validation of this concept appear in the methods section. This leads to the fifth and final hypothesis for testing:

H5. The coincident (direct relationship between the) adoption of organizational and IT innovations (synchronous innovation) will be directly and positively related to an integrated IT strategy.

The model in Figure 1 summarizes these five hypotheses. Note that there are important direct and indirect effects predicted in this model for the exogenous variables.

3. Methodology

The first phase of this project began with five in-depth case studies of companies chosen for their known, recent experience with collaborative engineering technologies. The companies represented a diverse set of industries: eye care, automotive and truck assembly, film and

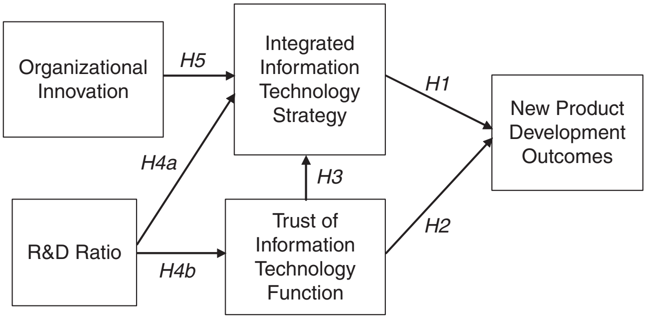


Figure 1. Proposed causal model

chemicals, and one small firm in contract plastic mold and prototype manufacturing. We spoke to over a dozen managers and technical support people in these five firms and had two complete demonstrations of collaborative engineering systems in order to begin developing our survey and interview protocols.

Upon completion of the pilot data collection and preliminary analysis, in the Summer of 2003, a survey was mailed to firms in other manufacturing and related economic sectors. The company or individual lists were obtained from professional societies (e.g. SME, ASME, IEEE, ASAE, TF&B, ISPE, IRI, and NSPE). Respondents comprised managers and key technical experts in the NPD process and had experience with collaborative engineering.

A final list of companies was created that represented firms with the highest R&D spending in SIC's 28, 35, 36, and 38[1]. Chief technical officers were identified as the best possible recipients for that mailing; 17,019 surveys were mailed out and returned with the greatest concentration in chemicals (SIC 28), fabricated metals (SIC 34), industrial machinery (SIC 35), electronics (SIC 36), transportation equipment (SIC 37), and instruments (SIC 38).

Of that mailing, 227 surveys to US firms were returned completed, with seven unusable (incomplete or not from target populations). Unidentified respondents and non-management respondents were eliminated and this included six unknown cases of which four could not be used leaving $n = 223$ for analysis. We determined the eligibility rate to be 10.4 percent. Our effective response rate was calculated at 12.43 percent ($220/(17{,}019 \times 0.104)$) and the usable response rate was determined to be 1.35 percent ($17{,}019 - 165 = 16{,}854$, $227/16{,}854 = 1.35$ percent). We found, as before, no evidence of response bias in these returns. Two weeks after the surveys were mailed out to the companies, we began making follow-up phone calls to increase the response rate and identify ineligible recipients. Companies were chosen by their SIC listing. Of those listings, 20 percent of non-respondent firms were contacted. Those firms were selected by random number generation and presented a representative sample of firms in that classification. Comparisons were then made between this sample of manufacturing firms and the Hoover's archive compiled on the Fortune 1000. From that analysis, no significant differences were found on sales ($t = 1.65$, ns), sales growth ($t = 1.66$, ns), employees ($t = 1.65$, ns), R&D expenditure ($t = 1.66$, ns), ROE ($t = 1.67$, ns), and current ratio ($t = 1.66$, ns).

3.1 Variables and measures

We predicted that several of firms' critical strategy and structure conditions are actionable variables, could be measured reliably, and would be significant predictors of our dependent variable in this study: the adoption of collaborative engineering systems. In all cases, we used sum-scale scores for the variable measure. We also asked two open-ended questions about the practices adopted by the firms.

3.2 Dependent variable: outcomes of the NPD process

A 12-item scale was developed to gauge the outcomes of the NPD process. This scale had a Cronbach's α of 0.78. Respondents were asked for each of 12 statements and, therefore, performance outcome dimensions, listed sequentially on the protocol, whether or not they thought the firm was doing better (coded 3), worse (coded 1), or about the same (coded 2) as competitors. The dimensions were:

(1) overall development costs;

(2) efficiency of product development investment (no waste);

(3) lead times;

(4) superiority of commercialization (e.g. IRR);

(5) improvement in product functionality/quality;

(6) improvement in elements of product technologies;

(7) major innovation in product technologies;

(8) major innovation in products as a whole;

(9) creation of new product concepts;

(10) improvement in the NPD process;

(11) reduction in quality problems; and

(12) surprise or delight, new product customers.

3.3 Trust in the IT function

Given the emergent importance of resolving the tension between the two technology cores of any organization, we included items on trust of the IT group as perceived by NPD professionals (usually engineers). We adapted the constructs and measures of Mayer and Davis (1999) by substituting the object of trust (here IT) in our questionnaire and items. The 16-item scale had a Cronbach's α of 0.84. In a comparable study, Rese and Baier (2011) reported a Cronbach's α of 0.65, but also found that that trust promoted network success ($r = 0.226$, $p < 0.01$), technological performance ($r = 0.199$, $p < 0.01$), financial performance ($r = 0.180$, $p < 0.05$), and network efficiency ($r = 0.323$, $p < 0.01$), but not market performance ($r = 0.104$, ns).

3.4 Integrated IT strategy

Integrated information systems are defined by Hasselbring (2000, p. 33) as "horizontal integration < of architecture layers meaningful to actual users of application systems > […] required to support the business process effectively […]." A number of studies have been published evaluating integrated IT systems in various contexts. For example, Gonzálvez-Gallego *et al.* (2015) studied integrated supply chain IT and Xu *et al.* (2011) evaluated an integrated medical supply information system in a pilot study of linking demand, inventory, decision support, and healthcare providers with great success. An integrated information system to coordinate regional tourism in China was documented by Wei (2011) in order to promote Chinese tourism with other countries. Another study summarized a flood information system for Iowa (Demir and Krajewski, 2013). We developed a three-item scale using the literature on IT, integrated technology strategy, and background provided by our pilot interviews of the five initial cases:

(1) the role of IT (three choices from traditional to evolving to integral, scored 1, 2, and 3 respectively);

(2) pursuit of the best talent for IT; and

(3) IT goals that stretch users' abilities.

The Cronbach's α for this scale was 0.69.

3.5 Organizational innovation

Our theory of successful adoption of new technology from outside the firm is dependent upon understanding appropriation conditions for innovation (e.g. Teece, 2000), organizational lag (e.g. Damanpour, 1987) as well as the research on purchased hardware-software systems (e.g. Ettlie and Reza, 1992). What this theory suggests is that when appropriation conditions are weak (or intermediate but not strong), organizational adaptations will be needed that are innovative but build on the culture of the adopting organization, in order to effectively capture rents from innovating. Synchronous innovation was originally introduced by Ettlie (1988) as simultaneous adoption of organizational and technological innovation.

The findings in Ettlie and Reza (1992) have been replicated and extended many times in published empirical studies. For example, Hervas-Oliver *et al.* (2014) studied process innovation strategies in 2,412 Spanish firms and found that, although R&D efforts are not positively related to production process performance, the latter is promoted by "synchronous co-adoption of organizational and technological innovation," (p. 873). In another, large-sample study of 8,172 firms (Mol and Birkinshaw, 2009) it was found that the adoption of new management practices is significantly associated with product and process innovation ($p < 0.01$). Ravichandran (1999) found that simultaneous adoption of administrative innovations and technological innovations promotes the successful re-use of software. Finally, Georgantzas and Shapiro (1993) surveyed 600 plant managers and derived four distinct models of synchronous innovation, all of which promote performance of product systems.

We used a six-item scale drawn from Ettlie and Reza (1992). The six items were scored 1, 0 for use and nonuse, and referred specifically to organizational adaptations to facilitate adoption of collaborative engineering systems: dotted-line reporting, increased autonomy, delegated purchase authority, job rotation, job changes, and new job titles. The scale has a Cronbach's α of 0.61.

4. Results

We first examined the qualitative responses to two open-ended questions to frame the context of the survey results. First, we asked what best practices these companies adopted in the NPD process; and second, what were the current challenges they faced in NPD (exact wording of the questions appears below). The results of the tabulated responses to these open-ended questions are presented first.

4.1 NPD best practices

Respondents filled in answers on the questionnaire/interview schedule to the following question: "What best practice(s) does your firm already exemplify in regards to NPD?" The answers are summarized in categories in Table I. In cases where there were multiple responses, just the first indicator was used. The most frequently mentioned response fell into the category design practices, with 27 (15.3 percent) of the complete data responses. What respondents included in this category were methods like test to failure (solid modeling, FMEA) or technology support (CAD/CAE) software, advanced intranet tools, technology re-use, etc.

The second most frequently mentioned best practice was quality, with 18 mentions (10.2 percent), such as Six Sigma programs, ISO certification, continuous improvement, and field testing. These first two categories accounted for over 25 percent of the responses. Third was integration of functions and coordination of effort, with 17 responses (9.6 percent) which included using teams including virtual collaboration, concurrent engineering, and communities of practice. The determination that integration of functions is critical to the NPD project (also mentioned in the next open-ended question responses as well) supports the inclusion of integrated technology strategy in *H1*, *H3*, and *H4a*, as well as *H4b*.

In the fourth place (Table I) is the voice of the customer, with 15 responses (8.5 percent) which typically involve a focused effort to capture wants and needs of clients through programs like quality function deployment and strong dependence on marketing. Fifth was R&D management with 12 answers (6.8 percent). This included portfolio analysis, lean R&D, project planning and management like road mapping, and product champions. Rounding out this cluster of reports was the use of stage-gate, modification of gate criteria, and other management methods like staging or phasing processes with 12 mentions (6.8 percent).

The next group of categories appears somewhat infrequently and is noteworthy for the absence of best practices exhibited by (and we assume emphasized by) these 177 reporting firms. Categories include speed or timing of market entry, and IT support. Both categories had six mentions each (3.4 percent). Perhaps it is noteworthy that 64 (36.2 percent) firms reported another factor or nothing at all to this question.

We concluded from these results that there are few surprises in these best practices, and firms tend to specialize or focus on a particular area for improvement and leadership to maximize the impact of their efforts in R&D and NPD. We suspect stage-gate and IT appear low (infrequently used) on the list for different reasons. Most firms are already using some form of phasing or gating procedure to manage projects, so being best is no longer a priority. On the other hand, speed and efficiency are still sought by most product firms, but they continue to struggle with this challenge. Category 5, R&D management, is perhaps the most interesting, not for its position in the table but for the type of experiments underway in these firms, which are often quite proprietary. Portfolio analysis and road mapping are enjoying a renewed emphasis in many companies with many nuanced and updated differences from the first time they were tried a decade or more ago (cf. Oliveira and Rozenfeld, 2010).

Integration of functions also deserves attention beyond its rank of third in the table. Since many firms are turning to open innovation alternatives to promote the NPD process, such as crowdsourcing and user innovation, this is a category that is likely to see a great deal of attention in coming years.

4.2 NPD challenges

Respondents were asked the following question: "In general, what are the broad issues that need to be resolved in your firm in order to be the 'best in class,' in NPD?" The results, again

Design practices (e.g. FMEA, CAD/CAE)	*f* = 27 (15.3%)
Quality (e.g. Six Sigma, etc.)	*f* = 18 (10.2%)
Integration of functions (e.g. teams)	*f* = 17 (9.6%)
VOC (e.g. QFD, marketing)	*f* = 15 (8.5%)
R&D management (e.g. lean R&D)	*f* = 12 (6.8%)
Stage-gate	*f* = 12 (6.8%)
Speed	*f* = 6 (3.4%)
IT (information technology)	*f* = 6 (3.4%)
Other/none/NA	*f* = 64 (36.2%)
Totals	177 (100%)

Table I.
NPD best practices

with the first mentioned factor listed, appear in Table II. The first factor listed combines comments generally focused on strategy and strategic challenges. Totally, 30 respondents (16.9 percent) mentioned this factor. Longer-term focus, management commitment, portfolio management, adherence to an established system by management, willingness to lead the market, etc., all fell into this category. This frequency exceeds the best practices leader (Table II), so it appears this carries some generic weight in the survey.

Tied for first place for reported challenges is cost of resources (e.g. people) in general with 30 mentions (16.9 percent). This is straightforward and very predictable. R&D and product managers generally want more resources, so making a case for this particular investment is really what seems to be behind this category. These combined for over a third (34 percent) of the top responses.

With the emergence of strategy and resources as critical issues in NPD processes, the rationale for including IT strategy and R&D intensity as predictors of new product success is justified, especially for *H1*, and *H3-H4b*.

Marketing and customer voice was a close third among challenges: with 29 mentions (16.4 percent), it is virtually tied with the first two categories. So we have a triumvirate of nearly equal issues identified by this group of firms: strategy, cost, and markets. These perennial issues, especially the integration and alignment of strategy that incorporates R&D, marketing, and other functions, always seem to challenge firms and continue to be part of the high stakes NPD game (cf. Ginn and Rubenstein, 1986; Rafael and Rubenstein, 1984).

A somewhat more distant fourth place from the Big Three is timing and speed with 19 mentions (10.7 percent). Since it is much higher in mentions here as a challenge than in Table I for best in class (only six mentioned it there), one has to assume that efficiency in the R&D and NPD process is still very much an issue with these, and probably most companies. This suggests that the need for speed (Brockhoff and Chakrabarti, 1988) has yet to become institutionalized within firms' NPD processes.

Rounding out the balance of the list of challenges is integration ($f = 16$, 9 percent) and formalization (12, 6.8 percent). When compared to Table I's results for best in class, these issues may be considered well in hand and perhaps not conquered, but more under control than the other issues in the top three of Table II. Quality, which appears last, with seven mentions (4 percent), also appears to fall into this last cluster of more or less under control issues in these reporting companies.

Overall, we can conclude that strategic focus, resources, functional integration, IT, and market or customer factors continue to be top issues in these companies. These issues echo findings generated over the past 50+ years, which necessitates a review of how effective firms are at implementing knowledge derived from academic studies (cf. Rubenstein and Schröder, 1977). Respondents did not refer to trust verbatim in responses to the open-ended questions. However, three of the four hypotheses that were tested do related directly to these non-directed reports.

Strategy	$f = 30$ (16.9%)
Cost/Resources (e.g. people)	$f = 30$ (16.9%)
Market/Customer	$f = 29$ (16.4%)
Timing/Speed	$f = 19$ (10.7%)
Integration (e.g. teams)	$f = 16$ (9%)
Formalization (e.g. stage-gate)	$f = 12$ (6.8%)
Quality	$f = 7$ (4%)
Other	$f = 22$ (12.4%)
na	$f = 12$ (6.8%)
Totals	$f = 177$ (100%)

Table II.
NPD challenges

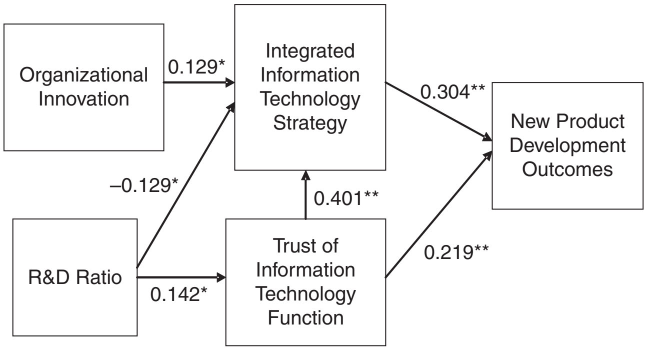
4.3 Survey results

For the quantitative protocols, we used several approaches to analyzing the survey data, including running individual regressions for each path, a three-stage least squares regression, a LISREL path analysis, and a LISREL structural equations model (SEM). The results were robust across different techniques. We report our results on the LISREL path analysis and SEM, which are the most conservative.

Results of the path analysis are presented in Figure 2. Descriptive statistics are reproduced in Table III. All five hypotheses were supported, with weaker statistical support for the two-part *H4*. All path coefficients are statistically significant, as are all regression equations. Mean substitution was used for missing data in all the results reported below, although the results are consistent with the case when missing values are dropped.

Integrated IT strategy and trust in IT account for a significant ($F = 26.2$, $p < 0.001$) amount of the variance in NPD outcomes ($R^2 = 0.193$, adjusted $R^2 = 0.185$). Trust in IT, organizational innovation, and R&D ratio ($\beta = -0.129$, as predicted) account for a significant ($F = 16.8$, $p < 0.001$) amount of variance in integrated IT strategy ($R^2 = 0.187$, adjusted $R^2 = 0.176$). Finally, R&D ratio accounts for a significant ($F = 4.6$, $p = 0.033$) amount of the variance in trust in IT ($R^2 = 0.02$, adjusted $R^2 = 0.016$).

The results of the SEM are presented in Figure 3. To address a problem of skewness and kurtosis of the indicators loading on the latent variable *L* outcome (NPD outcomes), we took



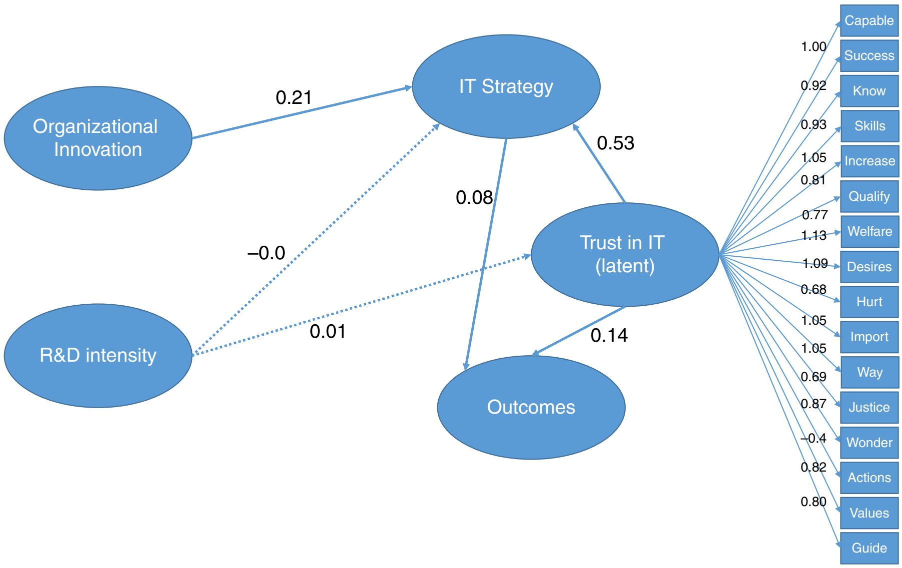
Notes: $^*p<0.05$; $^{**}p<0.01$

Figure 2.
Causal model results

Table III.
Descriptive statistics and correlation matrices

Variable	*n*	Mean	1	2	3	4
Excluding missing cases						
1 Performance	198	26.8	1.0			
2 Information technology strategy	185	0.91	0.43*	1.0		
3 Trust	212	44.8	0.36*	0.44*	1.0	
4 Organizational innovation	186	1.46	0.13	0.19*	0.08	1.0
5 R&D ratio[a]	194	15.0	0.01	–0.08	0.16*	–0.02
Including missing cases by substituting means						
1 Performance	223	26.8	1.0			
2 Information technology strategy	223	0.91	0.39*	1.0		
3 Trust	223	44.8	0.34*	0.39*	1.0	
4 Organizational innovation	223	1.46	0.11	0.16*	0.08	1.0
5 R&D ratio[a]	223	15.0	0.01	–0.07	0.14*	–0.01

Notes: [a]R&D ratio is highly skewed, the median is 6.0 percent. $^*p < 0.01$



Notes: χ^2=563.74, df=167, p<0.001, RMSEA=0.115

Figure 3.
SEM model estimates

the row average of all indicators of *L*outcome which led to an approximately normal distribution. These data were then used to build a single indicator latent variable, *M*outcome, which replaces *L*outcome. The resulting SEM model shows statistically significant relationships among the latent variables, and provides additional support for *H1-H3* but not for *H4* or R&D intensity predictions (Figure 3). These results are revisited in the "Discussion" section below. The model goodness-of-fit indicators are reasonable (CFI = 0.949, RMSEA = 0.115).

5. Discussion

A new perspective on managing technology deployment emerges from the findings of the current study. This new view could be called the tri-core model of the innovation process. In Daft's (1978) original dual-core model, technological and administrative cores supplied ideas for change in each core. Our findings suggest that a third core is required: the IT core. Our model predicted how new product success was directly associated with integrated IT and R&D-IT trust, and indirectly by organizational innovations and industry context (R&D ratios of firms in our sample). These hypotheses were supported (Tables IV and V). Organizational innovations

Independent variables	Performance	IT strategy	Trust
Trust	0.098 (0.029)***	0.055 (0.008)***	
Information technology strategy	0.997 (0.216)***		
Organizational innovation		0.138 (0.065)**	
R&D ratio		–0.007 (0.003)**	0.054 (0.025)**
Constant	21.6 (1.28)***	–1.64 (0.38)***	44.0 (0.75)***
R^2	0.193	0.187	0.020
Adjusted R^2	0.185	0.176	0.016
F-statistic	26.2***	16.8***	4.58**

Notes: $^{**}p < 0.05$; $^{***}p < 0.01$

Table IV.
Regression summaries predicting NPD outcomes (OLS)

appear as significant, exogenous predictors, but indirectly act on outcomes through an integrated IT strategy. Core technology, as represented by the R&D ratio, also showed significant indirect impacts on outcomes. But information strategy and trust now emerge as the quintessential direct causal factors of the NPD process. The conclusion: in order to promote successful outcomes in the innovation process, all organizations need to take three cores into account simultaneously – administration, innovation core, and information core. Misalignment between one or more of these cores may lead to poor fit (Siggelkow, 2002), which leads to sub-optimal intra- and inter-organizational innovation.

Perhaps the most important implication of the findings of this study is that since the information function has a direct impact on new product success outcomes – by way of the degree to which an integrated strategy has been achieved and the extent of trust that product development teams have in the information function – information and knowledge management can no longer take a secondary or tertiary role in the NPD process. Three decades ago, there was great concern that the lack of strategic integration of the operations function in organizations was the root cause of competitive dysfunction (Ginn and Rubenstein, 1986). Now it appears that the same could be said about the information function.

5.1 Managerial implications

The managerial implications are important as well. The simple, glib directive to standardize IT across segments of the firm no longer applies here. Product development teams have unique needs not normally addressed by many centralized IT functions. The trust that members of these new offering development teams have in IT will be directly proportional to the degree to which needs are met, often with customized solutions to the current development challenges. Close examination of the first six items (abilities) and, especially, the next ten items (empathy and understanding) could be interpreted as a potential for customization, which is one component of customer satisfaction (Johnson and Ettlie, 2001). "Shadow IT," or the use of special, decentralized IT functions attached to organizational units, once prohibited in many firms, are now favored by many successful NPD firms (Bendoly *et al.*, 2012).

Further research on shadow IT appears to be warranted given these anecdotal reports of the importance of this wrinkle on corporate and divisional strategies. In general, this restructuring of the IT function would normally be considered contrary to the overall goal of this department or the IT function. As NPD becomes more important to the firm, it is likely that this variation on structuring information capability will become critical.

5.2 Limitations and future research

The findings of this study open up several avenues for future research as well, in both the areas of trust and of IT strategy. One limitation in our research design is that we looked cross-sectionally at projects that were already well underway and attempted to draw associations between the level of trust in the IT function and performance outcomes. However, the stage of the firm in the NPD process may be important in both establishing and maintaining trust, and that trust might fluctuate over time within the same firm. Thus,

Independent variables	Performance	IT strategy	Trust
Trust	0.142 (0.037)***	0.530 (0.125)***	
Information technology strategy	0.083 (0.021)***		
Organizational innovation		0.212 (0.07)***	
R&D ratio		−0.001 (0.004)	0.005 (0.003)*

Notes: Goodness-of-fit measures: Model CFI = 0.949; Model RMSEA = 0.115; Model $\chi^2 = 563.74$; degrees of freedom = 167. *$p < 0.10$; ***$p < 0.01$

Table V.
SEM regression summary

in firms with complex interactions between NPD/R&D and IT, future research may consider how trust influences the efficacy of innovation outcomes at different stages of the R&D process, especially at the project origin (cf. Oliveira and Rozenfeld, 2010).

We made no effort in this study to systematically code open-ended responses construct-wise, which are captured in categories (Tables I and II). It is gratifying that three of the four hypotheses were consistent with these open-ended responses. It is clear that a more direct link could be established in the future, but greater reliance on this integrated approach might include a natural language analysis (e.g. Shi *et al.*, 2016) as well as other qualitative methods that were beyond the scope of this original study, and the quality of the open-ended responses would need to be improved in order to justify linking them to other results. However, these results do provide a context for this and future research. For example, why does strategy continue to be a challenge (17 percent or responses) to the NPD process?

We were also unable to capture differences in organizational power across the different functions of the firm in the current study and how organizational and market power manifesting themselves at different levels of analysis might influence the outcomes (cf. Prasad and Rubenstein, 1992). Thus, future research may want to consider possible moderators, such as intra-organizational power, in which the different cores are endowed with higher status or decision-making rights; inter-organizational power, in which the different cores may be more (or less) influential with important alliance partners; and the overall effect of stakeholder bargaining power, in which the firm's ability to capture value from its own NPD processes relative to exchange partners (cf. Campbell *et al.*, 2012), may change the dynamics between the cores and the role of trust in the performance outcomes of the NPD process.

As we did not consider the dominant technological regime (Winter, 1984) governing the firm and alliance partners, future research may also tackle how such regimes may directly or indirectly influence trust, and how trust may vary across different regimes (Ceccagnoli, 2009; McGahan and Silverman, 2006; Rothaermel and Boeker, 2008; Rothaermel and Hill, 2005).

Although we were able to replicate OLS support in the SEM results for *H1-H3*, this was not the case for *H4a* and *H4b* (Table IV and Figure 2). This may suggest that there exist additional nuances regarding the relationship between R&D and IT for NPD; the complexity embedded within this relationship is likely beyond the reach of the current study methodology. It is also possible, based on open-ended question results that the R&D and marketing relationship is simply more important in NPD than the R&D/IT relationship. This comparative question might be raised in future research.

Finally, as mentioned above, open innovation methods that rely heavily on the IT core, such as crowdsourcing, are becoming more and more popular in R&D and problem solving (Afuah and Tucci, 2012). To be successful in crowdsourcing, the three cores of the firm may have to work even more closely together than for virtual teams. Thus, future research may tackle a broader spectrum of IT-enabled innovation methods and tools to see how important trust is in these different contexts. One wonders how a possible curvilinear relationship between R&D and IT on the trust variable might influence open innovation initiatives.

5.3 Conclusion

In this paper, we have examined how trust between the R&D and IT cores of the firm might influence NPD outcomes in a cross-industry, cross-sectional study. Higher levels of trust promote positive outcomes such as NPD success and increased integration between the IT function and the overall strategy of the firm, which is also positively associated with better outcomes. We therefore propose that there are benefits for the two "technology cores" of the firm to work well together and avoid unproductive conflict. It may ultimately be the role of top management referees in this potential conflict between R&D and the IT function and functional integration, in general (e.g. marketing) that predicts the outcomes.

Note

1. This is according to R&D Ratios & Budgets, Schonfeld & Associates Inc., copyright June 2002.

References

Afuah, A. and Tucci, C.L. (2012), "Crowdsourcing as a solution to distant search", *Academy of Management Review*, Vol. 37 No. 3, pp. 355-375.

Aldea, C., Popescu, A., Draghici, A. and Draghici, G. (2012), "ICT tools functionalities analysis of the decision making process of their implementation in virtual engineering teams", *Procedia Technology*, Vol. 5 No. 2, pp. 649-658.

Andriole, S.J. (2006), "The collaborate/integrate business technology strategy", *Communications of the ACM*, Vol. 49 No. 5, pp. 85-90.

Argyres, N.S., Bercovitz, J. and Mayer, K.J. (2007), "Complementarity and evolution of contractual provisions: an empirical study of IT services contracts", *Organizational Science*, Vol. 18 No. 1, pp. 3-19.

Ashleigh, M.J. and Nandhakumar, J. (2007), "Trust and technologies: implications for organizational work practices", *Decision Support Systems*, Vol. 43 No. 2, pp. 607-617.

Baker, N., Siegman, J. and Rubenstein, A.H. (1967), "The effects of perceived needs and means on generation of ideas for industrial research and development projects", *IEEE Transactions on Engineering Management*, Vol. EM-14 No. 4, pp. 156-163.

Bakker, M., Leenders, R., Gabbay, S., Kratzer, J. and Van Engelen, J. (2006), "Is trust really social capital? Knowledge sharing in product development projects", *The Learning Organization*, Vol. 13 No. 6, pp. 594-605.

Bal, J. and Gundry, J. (1999), "Virtual teaming in the automotive supply chain", *Team Performance Management*, Vol. 5 No. 6, pp. 174-193.

Bendoly, E., Bharadwaj, A. and Bharadwaj, S. (2012), "Complementary drivers of new product development performance: cross-functional coordination, information system capability, and intelligence quality", *Production and Operations Management*, Vol. 21 No. 4, pp. 653-667.

Bidault, F. and Castello, A. (2008), "Capital and creativity in R&D project teams", *Sloan Management Review*, Vol. 38 No. 1, pp. 21-34.

Boutellier, R., Gassman, O., Macho, H. and Roux, M. (1998), "Management of dispersed product development teams: the role of information technologies", *R&D Management*, Vol. 28 No. 1, pp. 13-25.

Bouty, I. (2000), "Interpersonal and interaction influences on informal resource exchanges between R&D researches across organizational boundaries", *Academy of Management Journal*, Vol. 43 No. 1, pp. 50-65.

Bradley, R., Pridmore, J. and Byrd, T. (2006), "Information systems success in the context of different corporate cultural types: an empirical investigation", *Journal of Management Information Systems*, Vol. 23 No. 2, pp. 267-294.

Brattström, A., Löfsten, H. and Richtnér, A. (2012), "Creativity, trust and systematic processes in product development", *Research Policy*, Vol. 41 No. 4, pp. 743-755.

Brews, P. and Tucci, C.L. (2007), "The structural and performance effects of internetworking", *Long Range Planning*, Vol. 40 No. 2, pp. 223-243.

Brockhoff, K. and Chakrabarti, A.K. (1988), "R&D/marketing linkage and innovation strategy: some West German experience", *IEEE Transactions on Engineering Management*, Vol. 35 No. 3, pp. 167-174.

Bunduchi, R. (2013), "Trust, partner selection and innovation outcome in collaborative new product development", *Production Planning & Control: The Management of Operations*, Vol. 24 Nos 2-3.

Campbell, B.A., Coff, R. and Kryscynski, D. (2012), "Rethinking sustained competitive advantage from human capital", *Academy of Management Review*, Vol. 37 No. 3, pp. 376-395.

Ceccagnoli, M. (2009), "Appropriability, preemption, and firm performance", *Strategic Management Journal*, Vol. 30 No. 1, pp. 81-98.

Chae, B., Yen, H.R. and Sheu, C. (2005), "Information technology and supply chain collaboration: moderating effects of existing relationships between partners", *IEEE Transactions on Engineering Management*, Vol. 52 No. 4, pp. 440-448.

Chakrabarti, A.K. and O'Keefe, R.D. (1977), "A study of key communicators in research and development laboratories", *Group & Organization Management*, Vol. 2 No. 3, pp. 336-346.

Chan, Y.E., Huff, S.L., Barclay, D.W. and Copeland, D.G. (1997), "Business strategic orientation, information systems strategic orientation, and strategic alignment", *Information Systems Research*, Vol. 8 No. 2, pp. 125-150.

Chen, C.-J. (2004), "The effect of knowledge attribute, alliance characteristics, and absorptive capacity on knowledge transfer performance", *R&D Management*, Vol. 34 No. 3, pp. 311-321.

Clercq, D.D., Thongpapanl, N. and Dimov, D. (2009), "When good conflict gets better and bad conflict becomes worse: the role of social capital in the conflict-innovation relationship", *Journal of the Academy of Marketing Science*, Vol. 37 No. 3, pp. 283-297.

Coff, R.W. (1999), "When competitive advantage doesn't lead to performance: the resource-based view and stakeholder bargaining power", *Organization Science*, Vol. 10 No. 2, pp. 119-133.

Daft, R.L. (1978), "A dual-core model of organizational innovation", *Academy of Management Journal*, Vol. 21 No. 2, pp. 193-210.

Dahl, M.S. and Pedersen, C.O. (2005), "Social networks in the R&D process: the case of the wireless communication industry around Aalborg, Denmark", *Journal of Engineering and Technology Management*, Vol. 22 Nos 1-2, pp. 75-92.

Damanpour, F. (1987), "The adoption of technological, administrative, and ancillary innovations: impact of organizational factors", *Journal of Management*, Vol. 13 No. 4, pp. 675-688.

Demir, I. and Krajewski, W. (2013), "Towards an integrated food information systems: centralized data access, analysis and visualization", *Environmental Modelling & Software*, Vol. 50, December, pp. 77-84.

Dodgson, M. (1993), "Learning, trust, and technological cooperation", *Human Relations*, Vol. 46 No. 1, pp. 77-95.

Ebrahim, N.A., Shamsuddin, A. and Taha, Z. (2009), "Virtual teams for new product development: an innovative experience for R&D engineers", *European Journal of Educational Studies*, Vol. 1 No. 3, pp. 109-123.

Ebrahim, N.A., Shamsuddin, A. and Taha, Z. (2010), "SMEs; virtual research and development and R&D teams and new product development: a literature review", *International Journal of the Physical Sciences*, Vol. 5 No. 7, pp. 916-930.

Ettlie, J.E. (1988), *Taking Charge of Manufacturing*, Jossey-Bass, San Francisco, CA.

Ettlie, J.E. (1998), "R&D and global manufacturing performance", *Management Science*, Vol. 44 No. 1, pp. 1-11.

Ettlie, J.E. and Reza, E. (1992), "Organizational integration and process innovation", *Academy of Management Journal*, Vol. 34 No. 4, pp. 795-827.

Fredericks, E. (2001), "Trust in new product development teams: a conceptual framework and research propositions", in Krishnan, R. and Viswanathan, M. (Eds), *Proceedings of the American Marketing Association Winter Educators' Conference*, American Marketing Association, Chicago, IL, p. 61.

Fulmer, C.A. and Gelfand, M.J. (2012), "At what level (and in whom) we trust across multiple organizational levels", *Journal of Management*, Vol. 38 No. 4, pp. 1167-1230.

Gallié, E. and Guichard, R. (2005), "Do collaboratories mean the end of face-to-face interactions? An evidence from the ISEE project", *Economics of Innovation and New Technology*, Vol. 14 No. 6, pp. 514-532.

Geisler, E. and Rubenstein, A.H. (1987), “The successful implementation of application software in new production systems”, *Interfaces*, Vol. 17 No. 3, pp. 18-24.

Georgantzas, N. and Shapiro, H.J. (1993), “Viable theoretical forms of synchronous production innovation”, *Journal of Operations Management*, Vol. 11 No. 2, pp. 161-183.

Ginn, M.E. and Rubenstein, A. (1986), “The R&D/production interface: a case study of new product commercialization”, *Journal of Product Innovation Management*, Vol. 3 No. 3, pp. 158-170.

Griffin, A. and Hauser, J. (1996), “Integrating R&D and marketing: a review and analysis of the literature”, *Journal of Product Innovation Management*, Vol. 13 No. 3, pp. 191-215.

Griffith, T.L., Sawyer, J.E. and Neale, M.A. (2003), “Virtualness and knowledge in teams: managing the love triangle of organizations, individuals, and information technology”, *MIS Quarterly*, Vol. 27 No. 2, pp. 265-287.

Gonzálvez-Gallego, N., Molina-Castillo, F.-J., Soto-Acosta, P., Varajao, J. and Trigo, A. (2015), “Using integrated information systems in supply chain management”, *Enterprise Information Systems*, Vol. 9 No. 2, pp. 210-232.

Gupta, A.K., Raj, S.P. and Wilmon, D. (1986), “A model for studying R&D-marketing interface in the product development process”, *Journal of Marketing*, Vol. 50 No. 2, pp. 7-17.

Hasselbring, W. (2000), “Information systems integration”, *Communications of the ACM*, Vol. 43 No. 6, pp. 33-38.

Heinz, U., Baga, T., Gebert, D. and Kearney, E. (2006), “Leadership and cooperation as success factors in innovative R&D projects on electronic platforms”, *Team Performance Management*, Vol. 12 Nos 3-4, pp. 66-76.

Henttonen, K. and Blomqvist, K. (2005), “Managing distance in a dynamic environment: the role of trust in a virtual team in a global telecommunications company”, *Journal of Strategic Change*, Vol. 14 No. 1, pp. 107-119.

Hervas-Oliver, J.L., Sempre-Ripoll, F. and Boronat-Moll, C. (2014), “Process innovation strategy in SMEs, organizational innovation and performance: a misleading debate?”, *Small Business Economics*, Vol. 43 No. 4, pp. 873-886.

Hoecht, A. (2004), “Control in collaborative research and technology development: a case study in the chemical industry”, *Journal of Managerial Psychology*, Vol. 19 No. 3, pp. 218-234.

Huber, F. (2011), “On the role and interrelationship of spatial, social, and cognitive proximity: personal knowledge relationships of R&D workers in the Cambridge information cluster”, *Regional Studies*, Vol. 46 No. 9, pp. 1169-1182.

Huberman, B.A., Wu, F. and Zhang, L. (2005), “Ensuring trust in one time exchanges: solving the QoS problem”, *Netnomics: Economic Research and Electronic Networking*, Vol. 7 No. 1, pp. 27-37.

Jarvenpaa, S.L., Shaw, T.R. and Staples, D.S. (2004), “Toward contextualized theories of trust: the role of trust in global virtual teams”, *Information Systems Research*, Vol. 15 No. 3, pp. 250-267.

Jian, Z.Q., Liu, R. and Zhao, L.Z. (2010), “The impact of network relationship, trust, and knowledge sharing on technology innovation performance”, *R&D Management*.

Jiang, X., Li, M., Gao, S., Bao, Y. and Jiang, F. (2013), “Managing knowledge leakage in strategic alliances: the effects of trust and formal contracts”, *Industrial Marketing Management*, Vol. 42 No. 6, pp. 983-991.

Johnson, M. and Ettlie, J.E. (2001), “Technology, customization and reliability”, *Journal of Quality Management*, Vol. 6 No. 2, pp. 193-210.

Kappel, T. and Rubenstein, A. (1999), “Creativity in design: the contribution of information technology”, *IEEE Transactions on Engineering Management*, Vol. 46 No. 2, pp. 132-143.

Kasper-Fuehrer, E. and Ashkanasy, N. (2003), “The inter-organizational virtual organization”, *International Studies of Management and Organization*, Vol. 33 No. 4, pp. 34-64.

Kegan, D. (1971), “Organizational development: description, issues and some research results”, *Academy of Management Journal*, Vol. 14 No. 4, pp. 453-464.

Kegan, D. and Rubenstein, A.H. (1973), "Trust, effectiveness, and organizational development: a field study of R&D", *Journal of Applied Behavioral Science*, Vol. 9 No. 4, pp. 498-513.

Keller, R.T. (1994), "Technology-information processing fit and the performance of R&D project groups: a test of contingency theory", *Academy of Management Journal*, Vol. 37 No. 1, pp. 167-179.

Kettenger, W.J., Grover, V., Guha, S. and Segars, A. (1994), "Strategic information systems revisited: a study in sustainability and performance", *MIS Quarterly*, Vol. 18 No. 1, pp. 31-58.

Kleis, L., Chwelos, P., Ramirez, R. and Cockburn, I. (2012), "Information technology and intangible output: the impact of IT investment on innovation productivity", *Information Systems Research*, Vol. 23 No. 1, pp. 42-59.

Korsgaard, M.A., Bower, H.H., Lester and S.W. (2015), "It isn't always mutual: a critical review of dyadic trust", *Journal of Management*, Vol. 41 No. 1, pp. 47-70.

Kyriazis, E., Couchman, P. and Johnson, L.W. (2012), "Psychosocial antecedents of communication, trust, relationship effectiveness in new product development projects: a functional manager perspective", *R&D Management*, Vol. 42 No. 3, pp. 207-224.

MacDonald, S. and Piekkari, R. (2005), "Out of control: personal networks in European collaboration", *R&D Management*, Vol. 35 No. 4, pp. 441-453.

McGahan, A.M. and Silverman, B.S. (2006), "Profiting from technological innovation by others: the effect of competitor patenting on firm value", *Research Policy* 35 No. 8, pp. 1222-1242.

Madhavan, R. and Grover, R. (1998), "From embedded knowledge to embodied knowledge: new product development as knowledge management", *Journal of Marketing*, Vol. 62 No. 4, pp. 1-12.

Majchrzak, A., Rice, R.E., Malhotra, A., King, N. and Ba, S. (2000), "Technology adaptation: the case of a computer-supported inter-organizational virtual team", *MIS Quarterly*, Vol. 24 No. 2, pp. 569-600.

Maurer, I. (2010), "How to build trust in inter-organizational projects: the impact of project staffing and project rewards on the formation of trust, knowledge acquisition and product innovation", *International Journal of Project Management*, Vol. 28 No. 7, pp. 629-637.

Mayer, R.C. and Davis, J.H. (1999), "The effect of the performance appraisal system on trust for management: a field quasi-experiment", *Journal of Applied Psychology*, Vol. 84 No. 1, pp. 123-136.

Mayer, R.C., Davis, J.H. and Schoorman, F.D. (1995), "An integrative model of organizational trust", *Academy of Management Review*, Vol. 20 No. 3, pp. 709-734.

Miles, R.E., Snow, C.C., Meyer, A.D. and Coleman, H.J. Jr (1978), "Organizational strategy, structure, and process", *The Academy of Management Review*, Vol. 3 No. 3, pp. 546-562.

Mol, M.J. and Birkinshaw, J. (2009), "The sources of management innovation: when firms introduce new management practices", *Journal of Business Research*, Vol. 62 No. 12, pp. 1269-1280.

Moenaert, R.K. and Souder, W.E. (1990), "An information transfer model for integrating marketing and R&D personnel in new product development projects", *Journal of Product Innovation Management*, Vol. 7 No. 2, pp. 91-107.

Mora-Valentin, E.M., Montoro-Sanchez, A. and Geurras-Martin, L.A. (2004), "Determining factors in the success of R&D cooperative agreements between firms and research organizations", *Research Policy*, Vol. 33 No. 1, pp. 17-40.

Muethel, M., Hoegl, M. and Parboteeah, K. (2011), "National business ideology and employees' prosocial values", *Journal of International Business Studies*, Vol. 42 No. 2, pp. 183-201.

Muethel, M., Siebdrat, F. and Hoegl, M. (2012), "When do we really need interpersonal trust in globally dispersed new product development teams?", *R&D Management*, Vol. 42 No. 1, pp. 31-46.

Nooteboom, B. (2013), "Trust and innovation", *Handbook of Advances in Trust Research*, Edward Elgar Publishing, Cheltenham, pp. 106-121.

Oliveira, M.G. and Rozenfeld, H. (2010), "Integrating technology roadmapping and portfolio management at the front-end of new product development", *Technological Forecasting and Social Change*, Vol. 77 No. 8, pp. 1339-1354.

Park, J. and Lee, J. (2014), "Knowledge sharing in information systems development projects: explicating the role of dependence and trust", *International Journal of Project Management*, Vol. 32 No. 1, pp. 153-165.

Patton, M.A. and Josang, A. (2004), "Technologies for trust in electronic commerce", *Electronic Commerce Research*, Vol. 4 Nos 1-2, pp. 9-21.

Pepper, G. and Larson, G.S. (2006), "Overcoming information communication technology problems in a post-acquisition organization", *Organization Dynamics*, Vol. 35 No. 2, pp. 160-169.

Prasad, L. and Rubenstein, A.H. (1992), "Conceptualizing organizational politics as a multidimensional", *IEEE Transactions on Engineering Management*, Vol. 39 No. 1, pp. 4-12.

Rafael, I.D. and Rubenstein, A.H. (1984), "Top management roles in R&D projects", *R&D Management*, Vol. 14 No. 1, pp. 37-46.

Ravichandran, T. (1999), "Software reusability as synchronous innovation: a test of four theoretical models", *European Journal of Information Systems*, Vol. 8 No. 3, pp. 183-199.

Rese, A. and Baier, D. (2011), "Success factors for innovation management in networks of small and medium enterprises", *R&D Management*, Vol. 41 No. 2, pp. 138-155.

Rothaermel, F. and Boeker (2008), "Old technology meets new technology: complementarities, similarities, and alliance formation", *Strategic Management Journal*, Vol. 29 No. 1, pp. 47-77.

Rothaermel, F.T. and Hill, C.W.L. (2005), "Technological discontinuities and complementary assets: a longitudinal study of industry and firm performance", *Organization Science*, February, pp. 57-70.

Rubenstein, A.H. (1964), "Organizational factors affecting research and development decision making in large decentralized firms", *Management Science*, Vol. 10 No. 4, pp. 618-633.

Rubenstein, A.H. (1989), *Managing Technology in the Decentralized Firm*, Wiley Interscience, New York, NY.

Rubenstein, A.H. and Schröder, H. (1977), "Managerial differences in assessing probabilities of technical success for R&D projects", *Management Science*, Vol. 24 No. 2, pp. 137-148.

Rubenstein, A.H., Geisler, E. and Abeysinghe, R. (1997), "Industrial practices of research conversion and technology transfer", *Journal of Technology Transfer*, Vol. 22 No. 3, pp. 49-56.

Santoro, M.D. and Bierly, P.E. III (2006), "Facilitators of knowledge transfer in university-industry collaborations: a knowledge-based perspective", *IEEE Transactions on Engineering Management*, Vol. 53 No. 4, pp. 495-507.

Schoorman, F.D., Mayer, R.C. and Davis, J.H. (2007), "An integrative model of organizational trust: past, present and future", *The Academy of Management Review*, Vol. 32 No. 2, pp. 344-354.

Scott, J.E. (2000), "Facilitating inter-organizational learning with information technology", *Journal of Management Information Systems*, Vol. 17 No. 2, pp. 81-113.

Sen, F. and Rubenstein, A.H. (1989), "External technology and in-house R&D's facilitative role", *Journal of Product Innovation Management*, Vol. 6 No. 2, pp. 123-138.

Sen, F. and Rubenstein, A.H. (1990), "An exploration of factors affecting the integration of in-house R&D with external technology acquisition strategies of the firm", *IEEE Transactions on Engineering Management*, Vol. 37 No. 4, pp. 246-258.

Shi, Z.M., Lee, G.M. and Whinston, A.B. (2016), "Towards a better measure of business proximity: topic modeling for industry intelligence", *Management Information Systems Quarterly*, Vol. 40 No. 4, A1-A4.

Siggelkow, N. (2002), "Evolution toward fit", *Administrative Science Quarterly*, Vol. 47 No. 1, pp. 125-159.

Smith, P.G. and Blanck, E.L. (2002), "From experience: leading dispersed teams", *The Journal of Product Innovation Management*, Vol. 19 No. 4, pp. 294-304.

Song, M. and Zhao, Y. (1996), "Managing R&D-marketing integration in the new product development process", *Industrial Marketing Management*, Vol. 25 No. 6, pp. 545-553.

Teece, D.J. (2000), *Managing Intellectual Capital*, Oxford University Press, New York, NY.

Teece, D.J. (2006), "Reflections on 'profiting from innovation'", *Research Policy*, Vol. 35 No. 8, pp. 1131-1146.

Venkatraman, N. and Ramanujam, V. (1986), "Measurement of business performance in strategy research: a comparison of approaches", *Academy of Management Review*, Vol. 11 No. 4, pp. 801-814.

Wainwright, D. and Waring, T. (2004), "Three domains for implementing integrating information systems: redressing the balance between technology, strategic and organizational analysis", *International Journal of Information Management*, Vol. 24 No. 4, pp. 329-346.

Wei, M. (2011), "A research on the integrated information system applied to regional tourism cooperation", *International Journal of Advancements in Computing Technology*, Vol. 3 No. 2, pp. 118-129.

Weisenfeld, U., Fisscher, O., Pearson, A. and Brockhoff, K. (2001), "Managing technology as a virtual enterprise", *R&D Management*, Vol. 31 No. 3, pp. 323-334.

Winter, S.G. (1984), "Schumpeterian competition in alternative technological regimes", *Journal of Economic Behavior & Organization*, Vol. 5 Nos 3-4, pp. 287-320.

Willcocks, L. and Choi, C.J. (1995), "Co-operative partnership and 'total' IT outsourcing: from contractual obligation to strategic alliance?", *European Management Journal*, Vol. 13 No. 1, pp. 67-78.

Xu, E., Wermus, M. and Bauman, W.B. (2011), "Development of an integrated information medical supply information system", *Enterprise Information Systems*, Vol. 5 No. 3, pp. 385-399.

Yang, L., Chen, J. and Wang, H. (2012), "Assessing impacts of information technology on project success though knowledge management practice", *Automation in Construction*, Vol. 22, March, pp. 182-191.

Further reading

Gu, Q., Wang, G. and Wang, L. (2013), "Social capital and innovation in R&D teams: the mediating roles of psychological safety and learning from mistakes", *R&D Management*, Vol. 43 No. 2, pp. 89-102.

Lippert, S. and Forman, H. (2006), "A supply chain study of technology trust and antecedents to technology internalization consequences", *International Journal of Physical Distribution & Logistics Management*, Vol. 36 No. 4, pp. 271-288.

Moenaert, R.K. and Souder, W.E. (1996), "Context and antecedents of information utility at the R&D/marketing interface", *Management Science*, Vol. 42 No. 11, pp. 1592-1610.

Nicolaou, A.I. and McKnight, D.H. (2006), "Perceived information quality in data exchanges: effects on risk, trust, and intention to use", *Information Systems Research*, Vol. 17 No. 4, pp. 332-351.

Sabater, J. and Sierra, C. (2005), "Review on computational trust and reputation models", *The Artificial Intelligence Review*, Vol. 24 No. 1, pp. 33-60.

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