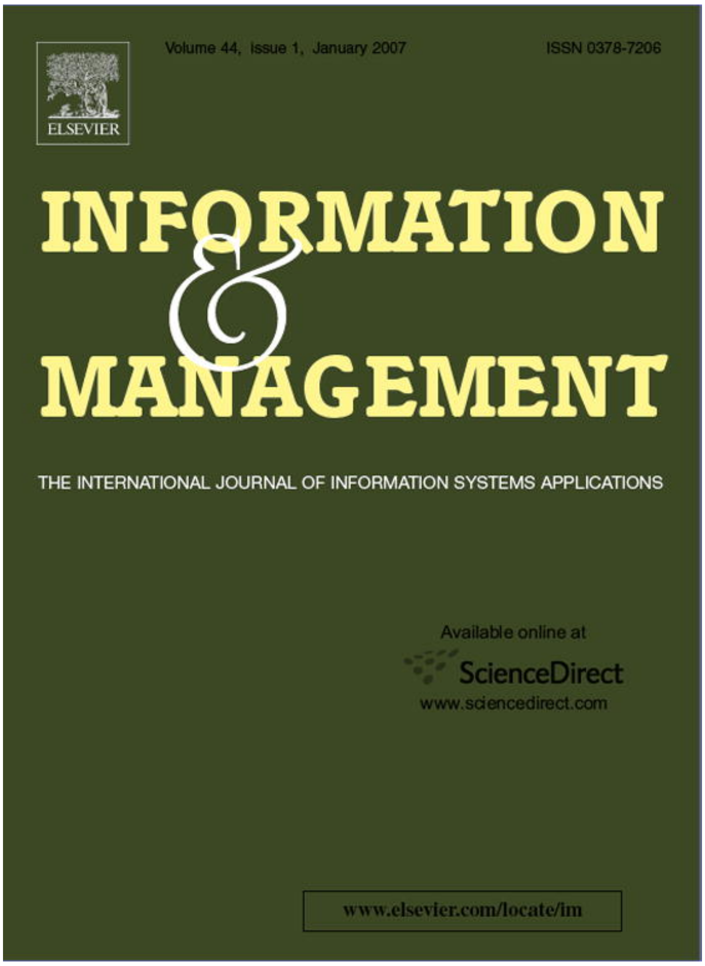
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How interfirm collaboration benefits IT innovation

Buraj Patrakosol [a], David L. Olson [b,*]

[a] *Chulalongkorn University, Bangkok, Thailand*
[b] *Department of Management, University of Nebraska, Lincoln, NE 68588-0491, USA*

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Abstract

Many studies have observed that close interfirm collaborations have positive effects on a firm's innovation. Yet, they have not shown how the collaboration contributes to this process. Higher innovation rates could be a result of revolutionary improvements, evolutionary improvements, or both. We investigated changes in the innovation process. Longitudinal data from 23 top IT firms across 9 years were collected and analyzed. Results suggested that close interfirm collaborations were associated with evolutionary but not revolutionary improvement. Results also suggested that the longer the IT firms had engaged in close interfirm collaboration, the larger the effect on IT innovations.

Keywords: Information technology investment; Information technology innovation; Interfirm collaboration; Social networks

1. Introduction

In the last decade, the IT industry has been an influential factor in global business; products and services have been created by utilizing IT and organizations are connected and conducting business in new ways. We investigated the contribution of close interfirm collaboration to the IT innovation process: our research question was ‘‘What are the natures of improvements in the IT innovation process associated with close interfirm collaborations?’’ Innovation positively contribute to the survival of the firm in dynamic business environments [22]. Generally, firms with higher innovation rates sustain higher profitability over the long-term [59]. However, as Downs and Mohr [24] pointed out, there are two aspects of organizational innovation studies. The first dealt with phenomena related to the *adoption and diffusion* of new innovations; in the IT area, examples include Moore and Benbasat [50], Fichman [27], and Swanson and Ramiller [63]. The second concerns innovation *creation*. Some examples of this from IT area are in King et al. [45], and Lyytinen and Rose [48]. The IT literature has included a number of studies relating to adoption using alternative terms such as implementation, incorporation, and routinization [11]. There is less work in the creation area [13,15,56,60].

For clarity, *IT innovation* is defined here as the generation and development of new ideas or organizational behaviors related to IT [21]. This emphasizes the creation of new IT artifacts and behaviors. A review of the literature suggested that studies of IT innovation had dealt with two aspects: *within-firm phenomena* and *groups of IT artifacts* (e.g., software and semiconductors). We argue for the importance of interfirm relationships, and take a holistic view of IT artifacts.

* Corresponding author. Tel.: +1 402 472 4521; fax: +1 402 472 5855.
E-mail address: dolson3@unl.edu (D.L. Olson).

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Since this does not relate specifically to a group of IT artifacts, the result suggests broader effects of interfirm relationship across multiple IT innovations.

2. Innovations from the IT industry

The IT industry has rapid innovation and intense competition [34]. It encompasses a wide array of businesses, the majority of which can be classified into software, telecommunication, semiconductor, and information services. The industry's main strategy is centered on intellectual innovation [65]. Unlike other industries, its innovations affect other businesses. IT innovations affect businesses both internally and externally. Internally, because they transform strategy and organizational structure; King [44] attributed the sharp increasing in organizational productivity and profitability in the 1990s to advances in IT development. Organization structure is often transformed when the use of IT increases. A study of 273 large firms [37] documented this. Firms with extensive IT had decentralized decision-making and greater emphasis on human capital. Furthermore, as the IT became pervasive and strategically important, managerial positions changed. CIO positions were created in recognition of the strategic importance of IT [30]. Virtual teams are now common.

In external environments, IT is a source of new ways of doing businesses when firms are connected electronically. Firms use new tools to connect business partners and customers [33]. The firm's boundary in the new economy is less clear [41].

IT innovation can occur at both a team- and firm-level. A primary need at the team-level is to determine factors influencing innovation by teams and their members. Internally directed teams have higher levels of innovation [68]. Teams with higher management expertise had higher performance [26].

The other level of analysis is at the firm-level and is the focus of our study; the creation of innovations is then the result of firm activities, factors, and processes. Studies of l have been conducted based on firm size, and governance structure [5,46]. More recent developments have included factors such as the impact of strategic decisions, knowledge, knowledge management, and top management. A case study of entry into the semiconductor business by four firms in the 1950s revealed the importance and the long lasting effects of decisions at the time of entry [39]. Essentially, the path and rate of innovation depended upon the firm's beginnings. Katila [42] considered the importance of knowledge age in the rate of IT innovation. Data from 131 robotic firms suggested that old knowledge from outside the industry positively affected the rate of innovation. However, old knowledge from inside the industry negatively affected it. Outside knowledge was useful because of its reliability and legitimacy. However, inside knowledge was rigid and obsolete for innovation with respect to innovation. A case study at Nortel Networks examined how and why knowledge management contributed to the firm performance [49], and the importance of both the knowledge management process and supporting information systems was identified. Nortel Networks was able to sustain competitiveness through innovation. A number of studies have investigated the effect of firm's top management on innovation [10,58]. Although top management may not directly contribute to the rate of innovation, the studies suggested that top management influenced it.

Three characteristics have emerged. First, most studies focused on only one IT sector at a time. Second, innovation was viewed as independent of intervention from the competitive environment. Third, the innovation process was viewed as a black-box. We therefore investigated a wide range of IT innovation by recognizing the IT industry as a whole. We also took the view that firm innovation was affected by the firm's external relationships, its social network and network resource. Finally, longitudinal data was collected to determine changes in the process due to the interfirm collaboration.

3. Social network and network resources perspective

Social network theory is important in understanding IT. Benson [9] suggested that interfirm networking or relationships can be considered to be a social network: interfirm networking is a political system and there are some resources that are exclusively available to the participants in the network. Gulati [31] calls these ''network resources''. They are like ''social capital'' [67]. Network resources are the result of interfirm networking and reside within network connections. Network participants may or may not choose to utilize these resources. Podolny and Page [55] suggested two basic ways to utilize network resources to produce innovation: by facilitating knowledge transfer from one firm to another and by becoming a place for sharing new knowledge. Network resources are believed to be multidimensional and depend on the configuration of the network.

The performance and behavior of a firm can be understood through analysis of its network and network resources. Interfirm networking has become imperative for enhancing innovation capability. Contractor et al. [20] identified five typical types of relationships in high-tech

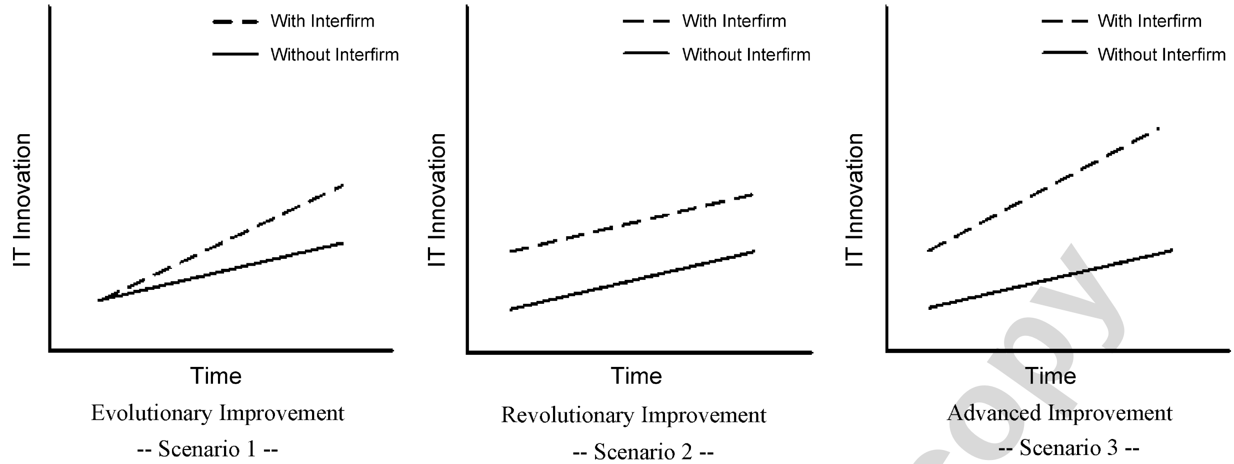

Fig. 1. Innovation scenarios.

industry: joint ventures, licensing, collaborative R&D, manufacturing agreement, and marketing agreement. Gulati et al. [32] divided relationships by closeness of collaboration (from arm's-length to close). Manufacturing and marketing agreements occupy the low end. At the top, R&D alliances and joint ventures have tighter relationships. Licensing usually occurs in the middle. Close interfirm collaborations have been documented to positively affect innovation [40].

4. Innovation process

Higher innovation from the innovation process could be a result of the three scenarios shown in Fig. 1.

Evolutionary improvement occurs when the process changes are incremental and gradual while revolutionary improvement occurs when the process is radically changed rapidly [62]. These two types are not mutually exclusive over time: a third scenario mixes them and is the most advanced. Any of the scenarios could explain observable increases in innovation due to close interfirm collaboration. Improvements of innovations were outside the scope of our study.

To hypothesize plausible effects of close interfirm collaboration on the innovation process, organizational learning and knowledge transfer literature were examined. A study in the semiconductor industry [35] revealed that learning and problem solving capability related to manufacturing processes were not compatible with radical process changes, because resources had to be reorganized and some were wasted in trouble-shooting. Another case study in the automobile industry studied knowledge utilization across teams [14]. Focal teams continued to use standard procedures when offered new knowledge from other teams and only slowly and incrementally integrated new knowledge. A study of DuPont also reported the role of internal firm knowledge networks with respect to inventions, finding that innovation was path-dependent [53]. These gave strong evidence of evolutionary improvement rather than rapid innovation. Therefore, we hypothesized:

Proposition 1. *Close interfirm collaborations contribute positively to the evolutionary improvement of IT innovation process.*

Proposition 2. *Close interfirm collaborations do not contribute to the revolutionary improvement of IT innovation process.*

These may appear to be redundant but we need both for clarity.

5. Research model and hypotheses

The causal model of the research question is shown in Fig. 2. IT innovation is assumed to be a function of close interfirm collaborations and firm size. The contribution of close interfirm collaboration is moderated by timeframes, the length of time that the firm exercises close interfirm collaboration.

A Hierarchical Linear Model (HLM) framework was used. The HLM framework is deemed appropriate because it mitigates various statistical problems in repeated observations design and increases statistical precision [57]. Virtually all longitudinal investigations can be conceptualized with this framework. Two levels of HLM equations can be expressed as [64]:

Level-1:

$$\mathrm{ITinno}_{ij} = \beta_{0i} + \beta_{1i}(\mathrm{Time}_{ij}) + \varepsilon_{ij} \quad (1)$$

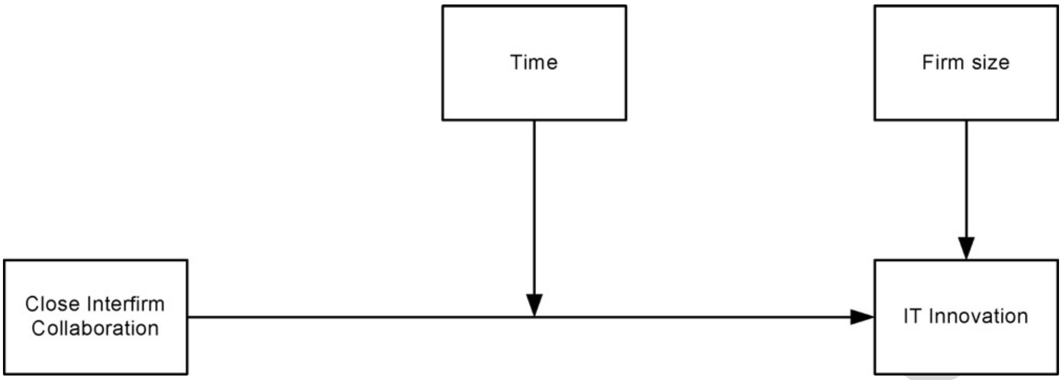

Fig. 2. A model of interfirm collaborations and IT innovations.

Level-2:

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(\text{CloseInterfirm}_i) + \gamma_{02}(\text{Size}_i) + \xi_{0i} \quad (2)$$

$$\beta_{1i} = \gamma_{10} + \gamma_{11}(\text{CloseInterfirm}_i) + \gamma_{12}(\text{Size}_i) + \xi_{1i} \quad (3)$$

By substituting β_{0i} and β_{1i} in Eq. (2), (3) into (1), the combined Eq. (3.5) is:

$$\begin{aligned} \text{Combined}: \quad \text{ITinno}_{ij} &= \gamma_{00} + \gamma_{01}(\text{CloseInterfirm}_i) \\ &+ \gamma_{02}(\text{Size}_i) + \gamma_{10}(\text{Time}_{ij}) \\ &+ \gamma_{11}(\text{CloseInterfirm}_i\,\text{Time}_{ij}) \\ &+ \gamma_{12}(\text{Size}_i\,\text{Time}_{ij}) + \xi_{0i} + \xi_{1i}(\text{Time}_{ij}) + \varepsilon_{ij} \quad (3.5) \end{aligned}$$

However, size is the control variable and the interaction term between size and time is not relevant in the context of our study. Therefore, it is removed from Eq. (3.5), thereby eliminating it from model coefficients. The variance due to the interaction term is transferred to error terms. The final form of combined-level is thus expressed as Eq. (4):

$$\begin{aligned} \text{Combined}: \quad \text{ITinno}_{ij} &= \gamma_{00} + \gamma_{01}(\text{CloseInterfirm}_i) \\ &+ \gamma_{02}(\text{Size}_i) + \gamma_{10}(\text{Time}_{ij}) \\ &+ \gamma_{11}(\text{CloseInterfirm}_i\,\text{Time}_{ij}) + \xi_{0i} \\ &+ \xi_{1i}(\text{Time}_{ij}) + \varepsilon_{ij} \quad (4) \end{aligned}$$

Here fixed effects are: γ_{00} is the IT innovation at the beginning; γ_{01} the contribution of close interfirm collaboration; γ_{02} the contribution of firm's size; γ_{10} the contribution of time (i.e., growth rate); γ_{11} is the contribution of interplay between the close collaboration and time.

Two parameters are particularly relevant to the two propositions. First, the evolutionary improvement in Proposition 1 can be examined at the contribution of parameter γ_{11}, which indicates the effects of close collaboration on IT innovations across the time horizon and captures the change of IT innovation due to close collaboration from one point in time to another. Evolutionary improvement carries the same effect. Improvements are not readily observable within a short period of time and therefore evolutionary improvement implies a *positive* contribution of γ_{11}. Hypothesis 1 is therefore:

Hypothesis 1. Close interfirm collaborations contribute positively to IT innovation when time horizon is taken into consideration.

Second, the parameter γ_{01} can be used to examine the revolutionary improvement in the Proposition 2. Parameter γ_{01} captures the effect of close interfirm collaboration when all other parameters are controlled; it points to any differences in IT innovations among *similar* firms with different close collaboration levels at the same timeframe. If parameter γ_{01} yielded positive contribution, the firm with higher level of close interfirm collaboration would have higher IT innovations. Existing differences among similar firms by the contribution of parameter γ_{01} suggest revolutionary improvement. Thus, Proposition 2 calls for *no* revolutionary improvement due to close interfirm collaborations and calls for *no* contribution from γ_{01}. Hypothesis 2 is therefore:

Hypothesis 2. Close interfirm collaborations provide no contribution to IT innovation at a given time.

6. Variables and measurement

6.1. IT innovation

IT innovation was measured by using a combined indicator based on R&D investment and patent citations of IT firms as shown in Fig. 3.

Traditionally, these have been used as the two indicators of innovation. However, neither is perfect:

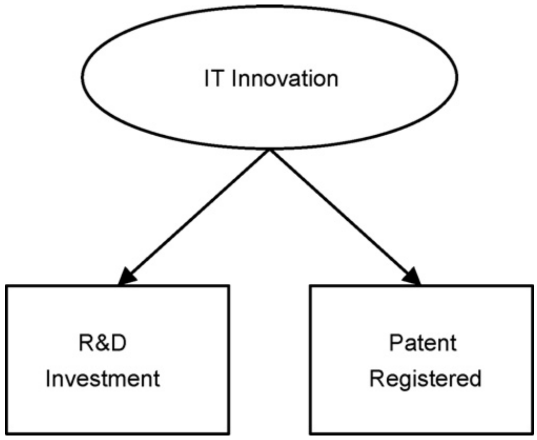

Fig. 3. Measurement model of IT innovation.

neither really represents the innovation output of a firm. Acs and Audrestsch [1] argued that R&D investment represented only the budgeted resources allocated towards innovation activities and not the resulting innovations. Patent citations were also limited because some inventions are not patented (possibly retained as trade secrets) and not all can be considered innovations. Notwithstanding this, Bayus et al. [6] demonstrated that R&D investment strongly and positively affected the introduction of new products. Helfat [36] also found that R&D investment is a good indicator of firm's innovation capability. Fleming and Sorenson [28] argued that the majority of patents represented the middle-to-upper spectrum of successful innovations from a firm. Patents also represent a strategic resource [3] and can be used to secure external funds [12]. Greve [29] asserted that an advantage of using patent citations is that such awards meet the official definition of technological innovation. Therefore, a combined indicator of IT innovation based on both R&D investment and patent citations of IT firms was implemented using a composite factor score.

6.2. Close interfirm collaboration

The independent construct in our study was the level of close interfirm collaborations. The construct was operationalized using the number of close interfirm ties. This is based on evidence that most firms are committed to their relationships and knowledge exchange [51]. The types of close interfirm ties in this research were identified by Gulati et al.'s interfirm relationship classification framework, which uses joint ventures and cross R&D alliances as close interfirm ties.

6.3. Firm size

Firm size had to be controlled because prior studies identified positive relationship between firm size and innovations [8]. Cohen and Levin [17] found that larger firms innovated more than smaller firms, and Kauffman and Mohtadi [43] cited studies indicating that larger firms could obtain greater efficiency in processes.

Traditionally, firm size is measured by total assets, total employees, or total sales. We used total sales because it is a robust indicator which has been used for many industries [52,54].

7. Data collection

Data was collected from three sources:

- Target IT firms and their IT innovations were drawn from data at the United States Patent and Trademark Office (USPTO).
- The R&D investments of the organizations were collected from the COMPUSTAT database.
- The numbers and kinds of interfirm relationships of IT firms with others was collected from the SDC platinum database. Although, this is not used as much as the COMPUSTAT database, it has been used in some studies [7] and has good reliability [16].

All data, except the relationships, were collected for years 1995 through 2003. During these 9 years, the IT industry experienced significant changes. In 2000, the industry suffered a great set back, which began to lift in 2001 and the industry has continued tp recover since then. Data about the numbers of interfirm relationships were collected from year 1994 to 2002; this 1-year difference was intended to include the temporal precedent relationship that could be expected in the dependent variable (IT innovation); i.e., interfirm relationships established during 1 year affect the next [25]. One year was implemented, following Ahuja [2] and Almeida and Phene [4].

The USPTO 1995 through 2003 reports were used to find possible firms and their numbers of patents. Target firms were selected after this. The final 23 most active US IT firms with the most complete data points across the 9 years were selected.

The COMPUSTAT database was then used to obtain R&D investment and total sales at the year-end for each target firm for the 9 years and finally the SDC platinum database was accessed to find the number of close interfirm relationships, defined as joint ventures and any

Table 1
Annual averaged data

Year	Patent citations (average)	R&D investment (average billion US$)	Firm size (average billion US$)	Close collaboration (rounded average)
1995	277	0.93	12.29	12
1996	334	0.99	12.83	8
1997	371	1.25	14.34	5
1998	521	1.31	14.70	7
1999	545	1.41	16.03	5
2000	596	1.69	18.24	7
2001	635	1.71	16.27	8
2002	632	1.61	15.69	5
2003	656	1.58	17.34	4

interfirm R&D alliance. The total for each target firm in the prior year were recorded.

Over these 9 years, top IT firms created about 515 patents and invested about US$ 1.4 billion in R&D annually. The year with most IT patent citations was 2003. The year with the highest R&D investment was 2001. On average, top IT firms engaged in seven close interfirm-collaborations annually. Table 1 presents annual averaged data from 1995 to 2003.

8. Results

The composite score of IT innovation was computed using the factor score of principle components factor analysis procedure. The newly created score had mean centered at zero and a variance of one. It can be seen in Table 2 that the IT innovation scores captured more than 80% of the variance in R&D investments and patent citations. The correlations between the IT innovation and R&D investments and between the IT innovation and patent citations were both 0.91. The high correlation indicated that IT innovation scores captured the two variables effectively. The IT innovation scores were then used to address the hypotheses. All variable in the model were entered into the HLM procedure using SPSS version 13. The parameter estimation method was maximum likelihood and the residual variances were set to be heterogeneous across two levels. All variables were entered without centering, which was not applied because the metric of the dependence variable was not empirically measured. Furthermore, given that data was not centered, the research question could still be answered by examining the fixed effect parameters. The HLM model had a good fit. The level-1 residual variance was less than 3%. The level-2 residual variance was less than 12% and the low residual variances across the two levels indicated that the study model explained the data well [23].

Table 3 lists all important fixed effects, their estimated standardized values, and their p-values. HLM provided significance tests for each under the null hypothesis that the estimated value is zero. The statistical significant level at 0.05 suggested that the value is not zero. It can be seen that firm size (γ_{02}) significantly and positively contributed to the IT innovation. Large IT firms innovated more than small IT firms. This observation upheld comments in the literature and was expected. However, an interesting observation was that the growth of IT innovation (γ_{10}) was only just statistically significant (p-value = 0.048), yet it contributed positively. The significance of γ_{10} was weak and suggested that IT firms created fewer IT innovations unless there were changes in other factors.

Table 2
Mean, standard deviation, and correlation for all variables in this study

	X	S.D.	1	2	3	4	5
1. IT innovation	0	1	1				
2. Firm size (billion US$)	15.4	19.3	0.86	1			
3. Close collaboration	6.6	10.0	0.56	0.62	1		
4. R&D investment (billion US$)	1.4	14.9	0.91	0.80	0.60	1	
5. Patent citation (100)	5.1	6.1	0.91	0.77	0.42	0.65	1

Note: (1) All correlations are significant at 0.05 level. (2) Time and the interaction term between time and close collaboration are not included because they are not empirically measured.

Table 3
Standardized parameter estimated and p-value

Parameter	Estimated parameter	p-Value
Close interfirm collaboration (γ_{01})	−0.001	0.682
Firm size (γ_{02})	0.047	0.000
Growth of IT innovation (γ_{10})	0.038	0.048
Interaction between growth and close interfirm collaboration (γ_{11})	0.002	0.021

The remaining two parameters (γ_{11} and γ_{01}) were keys to the two hypotheses. Hypothesis 1 called for positive contribution of interaction between close interfirm-collaboration and the time horizon (γ_{11}). The contribution of the interaction term (γ_{11}) was positive 0.002 with a p-value of 0.021 and was statistical significant. Hypothesis 1 was thus supported.

Innovation rate of an IT firm was increased by about 0.002 after a year with a close interfirm-collaboration. If the firm engaged in close interfirm collaboration, this benefit was multiply by the time and number of collaborations.

Hypothesis 2 called for no contribution of close interfirm-collaboration at a given time (γ_{01}). This hypothesis was confirmed. The contribution of close interfirm-collaboration (γ_{01}) had a p-value of 0.682 and it was statistically non-significant. The estimated parameter at −0.001 was due to random chance.

Both Hypotheses 1 and 2 were supported. Thus, a conclusion can be drawn that close interfirm-collaboration incrementally improved the IT innovation process. The observed increase in IT innovations when firms engaged in close interfirm-collaboration was a result of evolutionary incremental change over time. Also engaging in close interfirm-collaboration without taking time to maintain relationships does not help IT innovation.

Even though the research question was answered, HLM provided additional information showing that highly IT innovative firms did not always innovate more. The HLM estimated the covariance between the residual terms of Eqs. (2) (ξ_{0i}) and (3) (ξ_{1i}) at level-2. Covariance and the residual terms can be used to calculate correlations between the growth rate of IT innovation (γ_{10}) and IT innovation at the beginning (γ_{00}). This correlation explained how growth rate (γ_{10}) might be influenced by the initial status (γ_{00}) [38]. In our investigation, the correlation was 0.02 and was statistically non-significant (p-value = 0.913). Therefore, it can be concluded that, for our sample, the change in IT innovation does not depend on how firms initially innovated, given that size and close collaboration were taken into account.

9. Discussion

Our study addressed roles of close interfirm-collaboration in the process of IT innovation, asking "What are the improvements in the IT innovation process due to close interfirm collaborations?" We engaged in a longitudinal analysis of IT innovations in the context of close interfirm collaboration using data from 23 large IT firms analyzed in an HLM framework. Findings were:

(1) Firm size does matter. Large firms create more IT innovation than do small firms.
(2) The amount of IT innovations at a given point in time do not depend on the number of previous innovations. Highly IT innovative firms may not be able to sustain innovation.
(3) Increases in IT innovation rarely occur if a firm chooses not to increase size or to engage in interfirm-collaborations.
(4) The observed benefits of close interfirm-collaboration on IT innovation are the result of evolutionary improvement. IT firms do not instantly realize the benefits of close interfirm-collaboration on the IT innovation.

Close interfirm collaboration contributes positively to the evolutionary improvement of IT innovation process. There are two scholarly implications. An investigation by Li and Rajagopalan [47] found that immature processes are more open to revolutionary improvements but the evolutionary improvement finding of our study suggest that the innovation processes of large IT firms are already mature. In addition, our findings support the idea of absorptive capability development. Cohen and Levinthal [18] decided that the ability of a firm to evaluate and utilized outside knowledge is its absorptive capability. One of its characteristics is path-dependence [66]. The development of the capability largely depends on prior capability [19]. Evolutionary improvement is compatible with the path-dependence characteristic of absorptive capability. Evolutionary improvement and path-dependence are actually the same concept, based on the consequence function of the process's history [61].

Some implications for IT practitioners are:

- That IT firms should encourage a "stick to it" attitude; they should not expect great benefits quickly from close interfirm collaboration.

- The rate of IT innovation does not depend on the amount of IT innovation the firm created in the past.
- Both firm size and interfirm collaboration help firms gain IT innovation. If a firm cannot grow bigger, engaging in close interfirm collaboration is a viable alternative to increase IT innovation.

We acknowledge that the set of firms sampled may limit external validity. The firms had very intense IT innovation programs. Thus, the findings may present a challenge when they are generalized to firms with less intense IT innovation programs.

Appendix A. Selected IT firms

1. Advanced Micro Devices
2. Analog Devices
3. Apple Computer
4. Applied Materials
5. Cirrus Logic
6. Cisco
7. Dell
8. Hewlett-Packard
9. IBM
10. Intel Corporation
11. LSI Logic
12. Lucent Technologies
13. Micron Technology
14. Microsoft Corporation
15. Motorola
16. National Semiconductor
17. NCR Corporation
18. Qualcomm
19. Sun Microsystems
20. Texas Instruments
21. Unisys Corporation
22. United Microelectronics
23. Xerox Corporation

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Buraj Patrakosol recently graduated from the PhD program in Interdepartmental Business at the University of Nebraska, Lincoln. He is currently on the faculty at Chulalongkorn University. He has presented at Decision Sciences Institute meetings. His research interest is in the area of IT infrastructure, innovation, and interorganizational relationships.

David L. Olson is the James & H.K. Stuart professor in MIS and Othmer professor at the University of Nebraska. He has published research in over 80 refereed journal articles, primarily on the topic of multiple objective decision-making. He teaches in the management information systems, management science, and operations management areas. He has authored 10 books, some in multiple editions and languages. He has made over 100 presentations at international and national conferences on research topics. He is a member of the Association for Information Systems, the Decision Sciences Institute, the Institute for Operations Research and Management Sciences, and the Multiple Criteria Decision Making Society. He was named Best Enterprise Information Systems Educator by IFIP. He is a Fellow of the Decision Sciences Institute.