Developing the Readiness Index of IT-enabled Supply Chain Collaboration
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ABSTRACT

The goal of this paper is to identify the readiness of supply chain collaboration and design a measurement system to quantify them. The framework is first designed for a general IOS for supply chain collaboration. To further verify it, we apply the generic model to a specific case of implementing RosettaNet standards in high-tech industries. By calculating our proposed readiness index, each firm can determine where they are in terms of the collaboration stage and thereby draw roadmaps for better supply chain performance. From the empirical observations, technology readiness is the key condition for non-adopters to improve their readiness for adoption. Adopters develop their expansion strategies by first putting their focus on improving their business processes and then on improving their interactions with industrial environments. These findings provide companies a guideline for measuring their readiness for supply chain collaboration as well as the implementation strategies they should target on.

INTRODUCTION

Supply chain collaboration is enabled by advanced Internet technologies. Central to this solution is a web-based open standard that defines a common business language and an inter-company process methodology to enable process automation and facilitate Internet-based collaboration, communication, and commerce. Over the last two years, a number of universal, XML-based process standards have been developed for plentiful supply chain collaboration initiatives. The major works include the OASIS sponsored ebXML initiatives and the RosettaNet consortium sponsored by high-tech industries. Numerous solution providers have also started to develop inter-business applications that connect and manage communication among disparate enterprise systems and put supply chain collaboration in motion. Examples include Manugistics's enterprise profit optimization (EPO) solutions and Ariba and Commerce One's generic B2B services on procurement, order management, inventory, supply chain management, and so forth.

Yet little is known about the success factors of implementing such information technology. Supply chain collaboration requires a change in the incentive system for the organization and in many ways a re-tooling of the mindset of the entire organization. There is also a massive change in corporate mentality for internal operation. With nearly instant responses to the requests, the entire organization process has to mobilize at a far quicker pace. Besides, it is difficult to internally sell free sharing of information with vendors, customers, and third parties. Therefore, some successful factors for IOS adoption such as market power and customer lock-in (Chatfield and Bjorn Andersen 1997) may not have the same effects when considering collaborative information technologies.

Many IOS researchers and practitioners have developed various performance measurement systems that can be applied to evaluating supply chain collaboration (Kaplan and Norton 1992, Mukhopadhyay et al. 1995, Chatfield and Yetton 2000, Gebauer and Buxmann 2000). Ideally, those performance measurement systems should provide companies a guideline for designing implementation strategies and predicting value outcome. If the readiness of companies' development environments could be valued within the measurement model, organizations that have high readiness for supply chain collaboration could communicate this advantage to employees, shareholders, trading partners, and solution providers. Conversely, when companies have low readiness of supply chain collaboration, the score can immediately indicate the capabilities that organizations should enhance and the values that could be improved. Realistically, however, difficulties in placing a reliable value on supply chain collaboration readiness and linking it to the performance outcome make most of the researchers and practitioners preclude it from IT evaluation methodologies. Yet it is the very factor that is critical for the success of supply chain collaboration.

As a result, the objective of this research is to develop the index of supply chain collaboration readiness, denoted as I_R, complements measures of collaboration values with measures of value contributors and drivers. Applied to this study, companies can determine where they are based on their I_R, in terms of their adoption position in supply chain (SC) collaboration, and thereby can design suitable value strategies and roadmaps for achieving greater supply chain collaboration.

The article is organized as follows. The net section presents theoretical foundations for our proposed index of supply chain collaboration readiness. The index is then examined via data from RosettaNet member companies. We then turn to the managerial implications of using such an index, providing examples of company evaluations based on the RosettaNet data. The concluding section addresses the generalizability of our findings and opportunities for future research.

THEORETICAL BACKGROUND FOR SUPPLY CHAIN COLLABORATION READINESS

The theoretical foundation for supply chain collaboration readiness stems from two research areas: (1) IT readiness and (2) Inter-firm collaboration.

Research Relevant to Readiness of IT

The body of research that evaluates the readiness of IT is large and diverse. It can be summarized into three groups. The first group focuses on corporate technical ability that either encourage (e.g., relative advantage) or inhibit (e.g., complexity) realization of IT business values. Iacovou et al. (1995) have found firms with low IT integration level prohibit the benefits an adopter can receive given its IT capability. Premkumar et al. (1997) suggest that lack of technical knowledge and resources hinders IT use in small firms and is the main reason that smaller firms are less likely to adopt EDI. Nygaard-Andersen and Bjorn-Andersen (1994) also find the firms with low technical knowledge and resource organization are not likely to introduce EDI without external assistance, and any integration of EDI with existing systems is likely to be difficult.

The second group comprises the work attempting to gauge IT management issues and put emphasis on the corporate business processes. According to Massetti and Zmud (1996), using IT to manage the processes with large transaction volumes is likely to produce significant benefits. Grover (1993) also points out IT is often used to manage the processes that sell customized products as those processes requires intensive communication and decision making to reduce time spent and total errors made. When goods are of high value for an organization and are required recurrently, Hengst and Sol (1999) have found IT can be more successful in assisting companies utilize supply resources, improve order accuracy, and increase process flexibility.

The last group puts the interests on external factors that may mitigate the IT outcome, specifically with regard to exploiting IT capability to leverage relationships with business partners. Kumar and Dissel (1996) point out the importance of trust behavior in inter-organizational systems. When IT is deployed to manage inter-organizational processes, building trust among partners is a necessary condition for IT success because the fear of information leak may limit the system use. Besides trust, having compatible resources between partners is another important factor for implementing inter-organizational systems. Based on Premkumar et al. (1997), IT can be easily implemented when both parties have compatible resources.

Other researchers aim to create a general framework to explore the environmental readiness for IT. For instance, Iacovou et al. (1995) identify three aspects of a firm’s context (technology readiness, organization readiness, and external pressure) that are related to IT readiness. This proposed framework is examined latter by Chwelos et al. (2001). Bensaou and Venkatraman (1995) developed a model evaluating the fitness between IT and corporate existing environment. Three IT processing mechanisms for inter-organizational coordination are proposed: structural mechanisms (properties for information exchange), process mechanisms (climate underlying the information exchange), and information technology mechanisms (the intensity and scope of information exchange). This model is further examined by incorporating the characteristics of inter-organizational relationships and environment as the drivers of IT processing needs (Bensaou 1997).

While most of these studies target on pre-Internet IT such as EDI, they didn't consider the readiness factors associated with supply chain collaboration enabled by E-Business IT. Therefore there is a need to develop new readiness constructs that can represent the important features of supply chain collaboration. Further, the past research on IT readiness remains largely in the realms of conjecture and anecdote. This is a problem both in practice and in research. IS executives neither know the approach to measure their corporate readiness of IT nor have the knowledge to link the readiness to IT strategies. Corporations also have difficulties to change and influence their readiness of IT to improve the performance outputs. Consequently, we must identify the components of IT readiness that are measurable and common across firms and establish a general framework to explore the relationships among readiness, IT performance, and IT strategies.

Theories for Inter-Firm Collaboration

We review three theories that are related with inter-firm collaboration: (1) transaction cost theory, (2) political economy theory, and (4) critical mass theory. From the transaction cost theory perspectives, needs for collaboration stem from uncertainties. Williamson (1991) argues that asset specificity is the main risk to implementation of IOS links because the technology itself can be seen as a transaction-specific capital that it developed specifically for interaction with partners. Therefore many companies attempt to increase the dependence of their trading partners by selling and buying through IOS links.

Political economy theory provides dimensions underlying collaborative uncertainties. In contrast with transaction cost theory, political economy theory asserts that costs are not only from transactions involving specific assets but also from the underlying social system which comprises interacting sets of internal and external economic and socio-political forces that affect collective behavior and performance (Markus and Christiaanse 2003). Williamson (1979) argues that opportunisms resulting from man's bounded rationality are the main reason that market transactions are inefficient. Therefore, ability to generate trust is a fundamental entrepreneurial skill for lowering those costs and making the existence of the network economically feasible (Jarillo 1986).

While transaction cost theorists and political economy researchers recognize the environmental uncertainties among collaborative partners, in the critical mass theory perspective potential adopters are more interested in how the system that surrounds the innovator reacts to the innovation (Bouchard 1993). Marwell and Oliver (1993) integrated a diverse set of research findings to propose a framework describing four key factors affecting collective action: characteristics of the good produced from collective action, characteristics of the participants who comprise the collective group, the collective group of participants, and characteristics of the action processes that produce the good. This concept was then applied by a number of studies on various IOS research. For example, Bouchard (1993) developed a model to analyze the decision criteria for IOS adoption. The author argued the adoption decision are influenced by the scope of system use (i.e. how many others have already participated), the volume of system use (i.e. how much others have contributed), and the underlying partnership (i.e. who has participated). Tan et al. (2002) introduce the concept of organizational complementarity – defined as general compatibility among partners in terms of information and control systems, decision-making processes, and organizational culture, arguing that benefits accruing from IOS implementations seem to depend not only on a firm's internal contingencies but also on the complementary perspectives, decisions, and actions of its business partners. Their complmentarity concept highlights the fact that inter-organizational systems require shared governance.

In summary, the previous IT readiness studies suggest the importance of three categories of factors: technology, intraorganizational, and interorganizational. The critical mass theories suggest to considering the behavior of other adopters in the collaborative relationship: the intensity of technology use in the trading partner relationship and the complementary perspectives among partners. The transaction cost and political economy perspectives identify risk factors in the collaboration relationship: technology risk and socio-political risks. Combining all those dimensions as well as the factors discussed in previous IT readiness studies, we suggest the need to consider three sets of readiness factors in supply chain collaboration: corporate IT readiness, supply chain readiness, and market influence.

Table 1. Summary of readiness factors of supply chain collaboration

Factors	Theories/Description	Sources
Corporate IT Readiness	*IT readiness Studies*	
	Corporate IT capability	Nygaard-Andersen and Bjorn-Andersen (1994); Bensaou and Venkatraman (1995); Iacovou et al. (1995); Bensaou (1997); Premkumar et al. (1997); Chwelos et al. (2001)
	Transaction Cost Theory	
	Perceived IT risks	Williamson (1991)
Supply Chain Readiness	*IT Readiness Studies*	
	Characteristics of supply chain processes	Massetti and Zmud (1996); Grover (1993); Bensaou and Venkatraman (1995); Bensaou (1997); Hengst and Sol (1999)
	Quality of supply chain partnerships	Kumar and Dissel (1996), Premkumar et al. (1997)
	Social Political Theory	
	Collaborative uncertainties in supply chain partnerships	Williamson (1979); Jarillo (1986); Markus and Christiaanse (2003)
	Critical Mass Theory	
	Complementarity among supply chain partners	Tan et al. (2002)
Market Influence	*IT Readiness Studies*	
	External pressure	Iacovou et al. (1995); Chwelos et al. (2001)
	Social Political Theory	
	External economic forces	Markus and Christiaanse (2003)

RESEARCH MODEL

The literature reviewed above outlined important constructs and variables that should be included in the index of supply chain collaboration readiness. Figure 1 provides a pictorial depiction of the overall research mode. The model also contains the performance metrics of supply chain collaboration. But the metrics only pertains to the value impacts of supply chain collaboration, which are not enough for guiding supply chain collaboration activities where companies must make decisions about target processes, trading partners, and deployment levels. By complementing measures of collaboration values with measures of value contributors and drivers, corporate executives can now measure the readiness for current and future supply chain collaboration and how they must enhance internal technology and process capabilities and the investment in partnerships to improve performance of supply chain collaboration. The model also captures the stages of supply chain collaboration from non-adoption through high penetration. While each stage retains its focus on certain readiness factors and values, the theory clearly reveals the roadmap for superior supply chain collaboration.

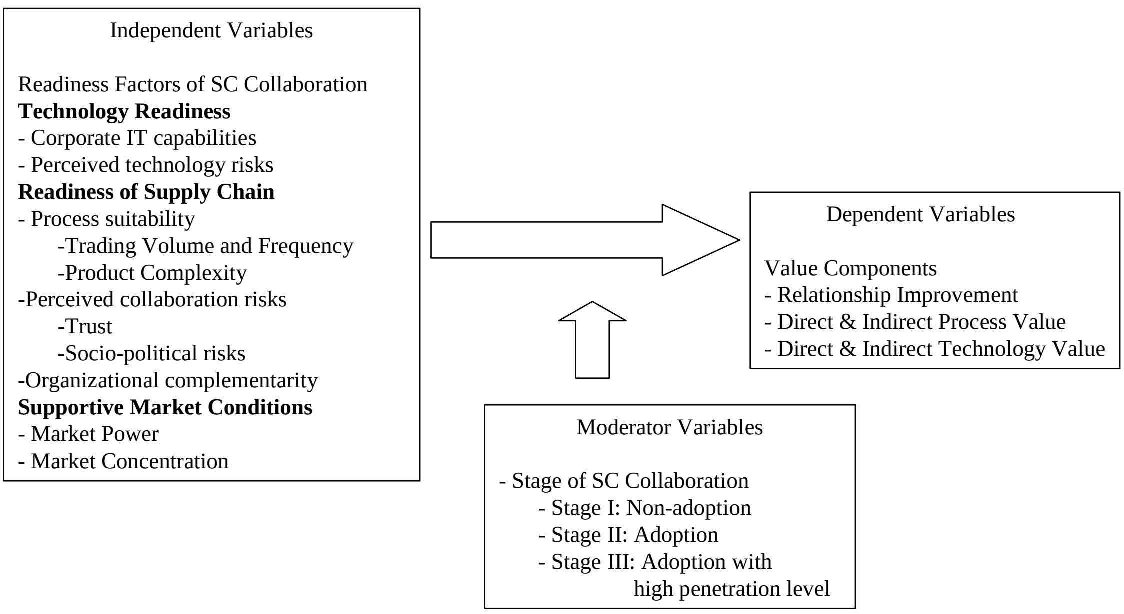

Figure 1. Research Model for Supply Chain Collaboration Readiness

Variables

The following paragraphs discuss the study's dependent, independent, and moderating variables.

Dependent Variables. As defined in Appendix Table A1, the dependent variables involve five valuation constructs: (1) direct technology value, (2) direct process value, (3) indirect technology value, (4) indirect process value, and (5) relationship improvement. We measure direct technology value in terms of six indicators capturing connection benefits, platform benefits, and IT personnel benefits in the research context (Byrd and Turner 2000, Duncan 1995, and Gibson 1993). Direct process value is operationalized with four indicators regarding the process automation benefits in cycle time reduction, information quality, and interest benefits. Indirect technology value in the research takes the form of IT future growth potential in the development of collaborative ITs. Specifically, these benefits include (1) learning benefits and (2) network effects ((Bakos and Treacy 1986, Barua et al. 1989, 1995, Brynjolfsson and Hitt 1998). We operationalize indirect process value using four indicators, tapping the benefits of improved information visibility after the inter-firm process standards have integrated with enterprise internal systems. We include the values from inventory cost reduction, capacity utilization improvement, and product management improvement (Hilton 1981, Kaplan and Norton 1993, Mukhopadhyay and Cooper 1993). The relationship improvement covers customer relationship improvement and trading partner/supplier relationship improvement. Two indicators are used to measure customer relationship improvement – capturing the benefits due to improved customer satisfaction and retention rate. Trading partner/supplier relationship improvement are measured using four indicators --coordination improvement, input quality improvement, and price reduction between trading partners and the firm (Bakos and Brynjolfsson 1993, Kaplan and Norton 1993, Porter 1985, Srinivasan et. al 1994, Mukhopadhyay et al. 1995).

Independent Variables. (1) Technology readiness. This construct is measured using two indicators designed to capture the corporate IT capability and perceived technology risks. As described in Appendix Table A2, corporate IT capability is measured by integration level and EDI usage level of corporate information systems. Perceived technology risks are measured using two indicators -- the level of asset specificity and system complexity.

(2) Readiness of Supply Chain. We measure this construct in terms of the process suitability, perceived collaboration risks, and organizational complementarity. Process suitability captures three process characteristics: process complexity, trading volume, and transaction frequency. Collaboration risks in this research take the form of the extent of perceived trust and socio-political risks between the firm and trading partners. Specifically, three indicators are used: in terms of the firm’s perception of the degree to which the trading partners have kept information confidential, provided sufficient support,

and defined clear responsibility. Organizational complementarity is measured at three levels: technology, organizational culture, and inter-organizational process. The details of the indicators are included in Appendix Table A3. Each indicator is measured on a 7-point scale from ‘strongly agree’ to ‘strongly disagree’.

(3) Supportive Market Conditions. We measure this construct in terms of market power, market fragmentation, and market variability. The details of the indicators are included in Appendix Table A4. Market power is operationalized as the extent to which the RN partners influence the adoption decision. The indicator is measured on a 7-point scale from ‘no influence’ to ‘strong influence’. Market uncertainty was operationalized with two indicators regarding the uncertainty the firm perceives due to the pricing and the new product introduction actions of the PIP trading partners. We measure market fragmentation using market concentration ratio CR 4, defined as the percentage of total industry sales contributed by the largest four firms (Veendorp 1983). The CR4 of the industries involved in this survey is described in Appendix Table A5.

Moderating Factors. We have two variables in this construct to categorize collaboration stages: (1) penetration level of supply chain collaboration and (2) scope of collaboration. The measurements of these variables are as follows.

(1) penetration level of supply chain collaboration (PA) is measured by asking "the percentage of transactions you have processed with your TOP trading partners via collaborative ITs"

(2) *Scope* of collaborative (PS) is measured by asking respondents: How many trading partners are connected to your organization through collaborative ITs?

Three stages of process sharing are classified based on these two dimensions. Non-adopters are those who (1) are not aware of the benefits of supply chain collaboration and have no intent to adopt or (2) those who may have perceived the benefits and are prepared to adopt but lack the necessary financial resources and technical expertise. Firms in stage two are considered *ready adopters*. They have the necessary resources to start developing IT for supply chain collaboration with a small scope of trading partners at low penetration level. They also recognize the benefits of utilizing supply chain resources to improve their business processes via collaboration. Firms in stage three are those who have successfully implemented the strategy of a broader but lower level of supply chain collaboration in exchange for wide adoption; they have started to maximize their exploitation of those built relationships via large penetration of collaborative IT.

Data Collection

To empirically test the research theory, we selected a sample population of RosettaNet current and potential member companies. RosettaNet, launched in 1998, is a non-profit consortium aimed at developing XML-based open process standards for the Electronic Components (EC), Information Technology (IT) and Semiconductor Manufacturing (SM) industries. The standard is structured into seven clusters of Partner Interface Processes (PIPs) for supporting firm-to-firm information exchange about general supply chain management, partner information profile, product and market information management, order management, inventory management, post-sale service support, and manufacturing support. The RosettaNet consortium provides appropriate data for study because by specifying the dialogues among firms and dictionaries that define the structure and contents of a XML document, RosettaNet PIPs enable an unprecedented level of collaboration among trading partners, which is called for by today's high-tech industrial supply chains.

To collect the data, a partnership was developed with the RosettaNet consortium in Spring 2003. A pilot survey was conducted with ten IT managers of RosettaNet member companies in Taiwan during the spring of 2003. These managers found no significant difficulties in filling the questionnaires. RosettaNet then helped distribute the survey to their 224 member companies (excluding the solution providers). The questionnaire was designed as an on-line survey form and its website address was emailed along with an introduction letter to managers in charge of RosettaNet standards development within these companies. The first survey was sent out in April 2003 and a second wave of the survey was sent out in June 2003. In total, we received 53 responses. The overall response rate was approximately 24%, which is close to a quarter of Rosettanet member companies.

More than half of the respondents have annual sales over $100 million. Twenty-five of the responding firms were already RosettaNet members and had implemented RosettaNet standards, ten companies were RosettaNet members but had not implemented RosettaNet standards, six companies had implemented RosettaNet standards but were not RosettaNet members, and twelve companies had neither implemented RosettaNet standards nor were members. Some salient characteristics of the responding executives, their firms, and RosettaNet adoption status are profiled in the Table 2.

Table 2. Characteristics of the Study Sample (n=53)

I.	**Characteristics of the Respondents:**	
	Job Title:	
	Director of IT/MIS	6
	IT/MIS manager	21
	E-Business manager	6
	RosettaNet program manager	5
	Others (sales/marketing manager, operation manager, business development manager)	15
II.	**Characteristics of the Company:**	

Annual Sales (US$):	
Less than 1 Million	5
1 Million – 10 Million	9
10 Million – 50 Million	6
50 Million – 100 Million	2
100 Million – 500 Million	7
500 Million – 1 Billion	3
Above 1 Billion	21
Industry Group:	
Telecommunication	5
Semiconductors	24
Information technology	6
Electronic components	12
Logistics/Transportation	6
Other	0
III. Characteristics of the RN Member Status	
RN Member & User:	25
RN Member:	10
RN User:	6
Non-Member & Non-User:	12

The sample size is small; however for quantitative analyses, samples in excess of thirty are considered adequate for most research (Hooley and West 1984). In spite of this citation, concerns may be raised over the power of the tests due to the small sample size. Since this survey is highly focused and in an exploratory sense, past research stated that the utilization of small sample size might be an appropriate use of resources for such study (Baroudi and Orlikowski 1989, Mahmood and Soon 1991).

Instrument Validity

Table 3 shows the Cronbach's alpha reliability coefficient value for each variable. For reliability coefficient values, Nunnally (1978) suggests a minimum of 0.80 for basic research and 0.9 for applied research that involves critical decision making. A number of variables such as relationship improvement and transaction volume & frequency have more than acceptable reliability coefficient values. Five variables have adequate reliabilities (direct technology value, indirect technology value, indirect process value, organizational complementarity, and market variability) and four variables (i.e. direct process value, IT capability, technology risks, and collaboration risks) appear to have less than adequate reliability, suggesting that the model should be used with caution in these areas. We also use the multitrait-multimethod approach described by Mahmood and Soon (1991) to assess the convergent and discriminant validity of collaboration value, technology readiness, supply chain readiness factors, and supportive market conditions. The result does not show serious problems and indicates we can proceed further with the statistical analysis of this model.

Table 3. Cronbach's alpha reliability coefficients for the final instrument (37 items)

Variables	No. of Items	Mean	S.d.	Cronbach's Alpha
Direct technology value	2	3.95	1.92	0.86
Indirect technology value	2	3.95	1.88	0.89
Direct process value	4	3.98	1.40	0.78
Indirect process value	4	4.00	1.85	0.84
Relationship improvement	6	4.05	1.93	0.90
IT capability	2	3.86	2.00	0.69
Technology risks	2	3.84	2.01	0.67
Transaction volume & frequency	2	4.00	1.98	0.91
Product complexity	1	3.27	1.53	Single Item
Collaboration risks	3	4.63	1.47	0.61
Organizational complementarity	3	4.16	1.99	0.88
Market power	1	5.43	1.49	Single Item
Market fragmentation	1	4.73	2.00	Single Item
Market variability	2	4.02	1.84	0.87
Penetration level	1	3.88	2.00	Single Item

Scope level	1	3.91	1.97	Single Item

MODEL ANALYSIS

Data Description

Because the phenomenon examined was multifaceted, rough patterns of differences between adopting and non-adopting firms were employed to track the effects of each readiness factors on the collaboration value presented above. Table 4 (column 1) shows the means and standard deviations of all variables used in the analyses. To identify the differences between RN adopters and non-RN adopters, we divide the total sample into two sub-samples: adopters and non-adopters (the last two columns of Table 4, which are designated in columns 2 and 3)[1]. We conduct t-tests to check statistically significant mean differences of defined variables between these two groups.

Table 4. Description of Variables

		All [1]	Adopter [2]	Non-Adopter [3]
		n = 53	n = 41	n = 12
		Mean *SD*	**Mean** *SD*	**Mean** *SD*
Dependent Variables				
1	Direct Technology Value	**3.95** *1.92*	**4.21** *1.86*	**3.47** *2.0*

[1] RN adopters are defined as the firms who had either been RosettaNet members or implemented RosettaNet standards or both, and "non-RN adopters" for those who had not.

2	Direct Process Value	**3.98** *1.40*	**4.17** *1.73*	**3,60** *2.20*
3	Indirect Technology Value	**3.95** *1.88*	**4.34**** *1.93*	**3.20** *1.57*
4	Indirect Process Value	**4.11** *1.94*	**4.00** *1.85*	**4.33** *2.16*
5	Relationship Improvement	**4.05** *1.93*	**4.07** *1.85*	**4.00** *2.14*
Independent Variables				
6	Corporate IT Capability	**3.86** *2.00*	**4.52***** *1.92*	**2.60** *2.50*
7	Perceived Technology Risks	**3.84** *2.01*	**3.41**** *2.10*	**4.67** *1.56*
8	Process Complexity	**3.27** *1.53*	**3.66***** *1.61*	**2.53** *1.06*
9	Transaction Volume & Frequency	**4.00** *1.98*	**4.59**** *1.88*	**2.87** *1.69*
10	Perceived Collaboration Risks	**4.63** *1.47*	**5.09***** *1.28*	**3.73** *1.44*
11	Organizational Complementarity	**4.16** *1.99*	**4.72***** *1.91*	**3.07** *1.71*
12	Market Power	**5.43** *1.49*	**5.52** *1.46*	**5.27** *1.58*
13	Market Fragmentation	**4.73** *2.00*	**4.41*** *2.16*	**5.33** *1.50*
14	Market Variability	**4.02** *1.84*	**3.83** *1.83*	**4.40** *1.84*
Moderators				
15	Penetration Level of PIPs	**3.88** *2.00*	**4.00** *2.08*	**3.33** *1.63*
16	Scope of PIPs	**3.91** *1.97*	**4.22**** *1.95*	**2.50** *1.52*

Note: Two-tailed significant level: *p<0.10, **p<0.05, ***p<0.01

37 out of 53 respondents have adopted RosettaNet (RN) process standards (PIPs). Among the six dependent variables, we find that adopters have significantly higher means for indirect technology value. This finding suggests that adopters perceive more PIP benefits from network effects and learning effects than non-adopters. We also find that adopters have significantly higher means for four independent variables. Those four variables are

(1) IT capability (row 7: 4.52 for adopters versus 2.60 for non adopters)

(2) product complexity (row 8: 3.66 versus 2.53)

(3) trading volume and frequency (row 9: 4.59 versus 2.87)

(4) perceived collaboration risks (row 14: 5.09 versus 2.73)

These findings show that adopters have higher technical capability than non-adopters and are likely to have closer and longer relationships with their trading partners. Further, adopters have significantly lower means for market fragmentation (row 11: 4.41 versus 5.53). This would apparently show the important role of contingency factors. The low market fragmentation of adopters may indicate adopters are likely to have larger size and competitive resources than adopters. We will test these associations further by the following multiple regression analyses.

Empirical Results

Regression models are built to find the hypothesized functional relationship among various readiness factors to the performance of supply chain collaboration. Let V be the total value of supply chain collaboration, where $V = \Sigma DV_i. + \Sigma IDV_j$. DV_i (i=1,2) represents the two direct value impacts of supply chain collaboration identified earlier (i.e. direct technology and process value) and IDV_j(j=1,2,3) are the three indirect value impacts of supply chain collaboration – indirect technology and process value and relationship improvement. Regress of V on the readiness factors. The model is stated below:

$$V = \alpha_0 + b_1\, IT\ capability + b_2\, technology\ risks + b_3\, product\ complexity + b_4\, transaction\ volume\ and\ frequency + b_5\, collaboration\ risks + b_6\, organizational\ complementarity + b_7\, market\ power + b_8\, market\ fragmentation + b_9\, market\ variability + \varepsilon \quad (1)$$

Table 5 summarizes the results of the regression analysis. The result shows that the value of R^2 is consistently associated with significant p values, indicating a reasonably good fit of the overall model. All the readiness factors except market power are statistically significant under certain collaboration stage. This implies supply chain collaboration may only be undertaken in a positive transactional climate between two organizations, where technology does not alter the balance of power significantly.

Table 5. Statistical Analysis for Each Stage of Supply Chain Collaboration

Company Roles\Readiness Factors	**Stage I: Non Adopters (n=12)**		**Firms in Stage II (n=21)**		**Firms in Stage III (n=20)**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
R^2	0.523	0.591	0.269	0.637	0.414	0.801
Sig. F	0.026	0.092	0.101	0.086	0.085	0.041
Technology Readiness	0.486*		0..409*		0.375	
IT Capability		0.105		0.513*		-0.340
Technology Risks		-0.414**		0.180		-0.119
SC Readiness	0.406		0.373*		0.491*	
Product Complexity		0.075		0.551*		-0.123

Trading Volume	0.140	-0.236	0.716***
Collaboration Risks	-0.174	-0.551*	-0.222
Org. Complementarity	0..796*	0.088	0.108
Supportive Market Con.	0.074	0.114	-0.575**
Market Power	-0.119	0.295	0.224
Market Frag.	0.016	-0.288	-0.357*
Market Variability	0.037	-0.185	-0.523*

Note. Stage (I) sample of non-adopters, (II) sample of small to medium scope of sharing (less than 5 partners) at low penetration level (less than 10% transactions through PIPs), (3) sample of large scope of sharing at low to high penetration level (more than 5 partners and more than 10% transactions through PIPs). Under each sample, two regressions are reported – The first one used the three readiness index categories, while the second one replaced the categories with the readiness factors in the regression. Entries reported above are coefficients. Significance levels: ***p≤0.01; **0.01<p≤0.05;* 0.05<p≤0.10.

As shown by its positive coefficient and significance level, higher technology readiness tends to be associated with higher performance of supply chain collaboration for the non-adopter sample. This suggests that companies perceive technology readiness as an important determinant in the adoption of supply chain collaboration. The result also shows that for non-adopters, decision to adopt supply chain collaboration is influenced by the level of perceived technology risks and organizational complementarity. This indicates a significant fear of lock-in and incomplementarity in non-adopter firms hinder adoption. Therefore, assisting these non-adopters to become more capable and knowledgeable of collaborative technologies becomes the main adoption strategy of supply chain collaboration, lending to our first finding:

Finding 1a: *Non-adopters require a greater level of corporate technology readiness before adoption*.

Finding 1b: *For initiators of supply chain collaboration, reducing the lock-in costs and improving organizational complementarity are the main strategies for encouraging adoption*

The regression analysis for firms in stage II also shows that the regression coefficient of *supply chain readiness* is positive and statistically significant (the value of the coefficient is 0.373 and statistically significant at the 10% level). This indicates that after adoption supply chain environment determines the further technology diffusion. The result also shows technology capability is positive and significant for firms in stage II (b: 513; $p<0.1$); that is the higher the IT capability, the larger the perceived benefits of expanding the adoption pool and the higher potential for further technology penetration. Product complexity is positively signed and statistically significant (b: 0.551, $p<0.1$), suggesting that product complexity increases the requirements for collaboration and encourages a higher scope of supply chain collaboration. The regression analysis also shows that *collaboration risk* is negative and statistically significant (the value of regression coefficient is -0.551 and statistically significant at the 0.1 level). This indicates that trustworthy relationships can safeguard transaction specific assets when initiating a high scope of supply chain collaboration. We summarize the findings as follows,

Finding 2a: *Companies require a ready supply chain environment for expanding the collaboration scope.*

Finding 2b: *Processes with the highest IT capability, product complexity, and trustworthy relationships should be chosen first when companies start to implement supply chain collaboration*

The analysis (stage III of Table 5) also shows supply chain readiness (b: 0.491; $p<0.1$) and market conditions (b: -0.575; $p<0.05$) are the key drivers for adopter firms which can develop large penetration levels with their trading partners. Comparing with firms in stage II, the result suggests that choosing trading partners for developing high levels of penetration, market conditions become a critical factor. Market fragmentation and variability are negatively and statistically significant with a b value of –0.357 ($p<0.1$) and -0.523 ($p<0.1$) respectively, showing organizations in concentrated and stable markets can have more resources to promote supply chain collaboration. It also suggests that processes with large trading volume and frequencies could generate higher collaboration value for firms in stage III. The b value of trading volume is 0.716 and statistically significant at the 0.01 level. Due to 'network externalities' and 'economies of scale," large trading volumes can make a higher penetration of supply chain collaboration more economically justifiable. Therefore, the findings can be summarized as follows,

Finding 3a. *A ready supply chain and supportive market conditions are key factors for firms to implement higher penetration of supply chain collaboration.*

Finding 3b. *For firms in stage III, partners with the large trading volume and in the stable and concentrated markets should be chosen first for penetration strategies.*

In summary, given the stage of supply chain collaboration we find companies have a mix of determinant conditions that decide the performance of supply chain collaboration. Specifically, supply chain process characteristics are important factors for achieving a higher scope of supply chain collaboration while corporate IT conditions are more important to adoption decisions. After companies build collaborative relationships with some partners and start to implement penetration strategies, market conditions become a critical factor. From this, we are able to provide an effective roadmap for achieving greater supply chain collaboration. The methodology to derive the roadmap will be discussed in the next section.

DISCUSSION

This section addresses the usefulness of our proposed readiness index, denoted as I_R, for determining corporate readiness for implementing supply chain collaboration and drawing the roadmap for better collaboration performance.

Applicability of the readiness index of supply chain collaboration (I_R)

How can we build a measurement system that translates a corporate current technology and supply chain situation into a measurable readiness index and thereby create roadmaps for better performance? We introduce three steps that enable an organization to develop roadmaps for its supply chain collaboration:

(1) Step 1: Calculate Index of Supply Chain Collaboration Readiness

(2) Step 2: Define Corporate current position of supply chain collaboration

(3) Step 3: Develop Roadmaps for Superior Supply Chain Collaboration

We discuss each of these stages in turn.

The methodology for calculating I_R. Using our proposed I_R, each firm can calculate its readiness for supply chain collaboration. Assume the higher the total readiness score, the more collaboration value can be obtained, the readiness index I_R can be calculated by the following function,

$$I_R = B_1 T_1 + B_2 T_2 + B_3 S_1 + B_4 S_2 + B_5 S_3 + B_6 S_4 + B_7 I_1 + B_8 I_2 + B_9 I_3 \qquad (2)$$

Where T_1 = IT capability
T_2 = technology risks
S_1 = product complexity
S_2 = trading volume and frequency
S_3 = collaboration risks
S_4 = organizational complementarity
I_1 = market power
I_2 = market fragmentation

I_3 = market variability

$B_1, B_2, \ldots, B_9$ = readiness score for each factor, which is derived from regression coefficients $b_1, b_2, \ldots, b_9$ of the regression function (1).

Using the RosettaNet survey study as an example, the readiness score B_i(i=1 to 9) can be obtained by regressing the total collaboration value on the readiness factors based on 53 cases we collected. Therefore, I_R can be estimated by the following function[2],

$$I_R = 0.513 \times T_1{}^{***} - 0.180 \times T_2 + 0.551 \times S_1{}^{**} + 0.236 \times S_2 - 0.185 \times S_3 + 0.088 \times S_4 + 0.295 \times I_1 - 0.551 \times I_2{}^{**} - 0.288 \times I_3{}^{*} \quad (3)$$

Based on our proposed measurements for each readiness index item (shown in Appendix A2, A3, and A4), companies can give a score between 1 and 7 for each readiness measurement, where 1 represents very small and 7 represents very large. Consider a situation that a company is at a level of readiness where technology capability (T_1) = 7, technology risks (T_2) = 7, product complexity (S_1) = 7, transaction volume and frequency (S_2) = 7, collaboration risks (S_3) = 1, organizational complementarity (S_4) = 7, market power (I_1) = 6, market fragmentation (I_2) = 6, and market variability (I_3) = 5; the total score of readiness I_R for this company equals to:

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[2] The value of R^2 is 0.637 (sig. F =0.036), suggesting that the model can explain 63.7% of the variance of I_R. Therefore it is adequate to derive the results. Significance levels: ***$p \le 0.01$; **$0.01 < p \le 0.05$;* $0.05 < p \le 0.10$.

$I_R = 0.531\times7 - 0.180\times7 + 0.551\times7 + 0.236\times7 - 0.185\times1 + 0.088\times7 + 0.295\times6 - 0.551\times6 - 0.288\times5 = 5.421$. We standardize it by dividing the case with highest value of I_R. In this example, the highest readiness score occurs under the conditions where technology risks, collaboration risks, fragmentation, and variability are equal to 1 and all other factors are 7. Therefore the standardized I_R for this company is 5.421/10.703 = 51 (%).

Define Corporate Current Position by I_R. To develop supply chain collaboration strategy, companies must first define their current position. The value of I_R can help them position themselves in stages of supply chain collaboration and thereby the corresponding readiness factors that can contribute the values can be derived. In our empirical observations, corporations show that three different stages of supply chain collaboration:

- Stage of non-adoption, where companies either have no intention to adopt or lack of capabilities to adopt
- Stage of high scope of sharing, where companies have already adopted supply chain collaboration and started to build the links with small to medium size of trading partners at low level of penetration
- Stage of high penetration of sharing, where companies have already built the supply chain collaboration with a group of trading partners and starts to implement it with high penetration level.

The survey data shows that there is a clear-cut I_R among the stages of supply chain collaboration (Figure 2). Therefore, we can verify that *firms in low stage of SC collaboration have low* I_R *and firms in high stage of SC collaboration have high* I_R. Using the sample example described in the last section, the company with I_R of 51 is mostly possible to fall into the category of stage II. However, the figure also shows that each stage overlaps with lower or higher stages; classification of the stages based on readiness score is not mutually exclusive. Therefore, companies who have low readiness still have the possibility of implementing higher stages of collaboration. This can result from socio-political issues such as the compatibility of organizational culture. From this point of view, the index also can act as an evaluation chart to justify whether the current implementation is beyond or above organizational capability.

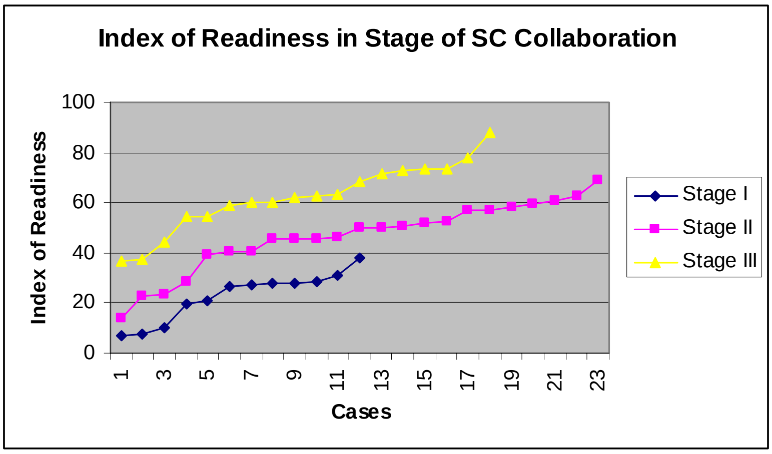

Figure 2. Index of Readiness in Stages of SC Collaboration

Develop Roadmaps for Superior Supply Chain Performance. After companies find their position, the next question is how to improve their readiness so as to achieve greater supply chain performance. From empirical observations, for non-adopters, technology readiness and organizational complementarity in the SC relationship are important value contributors (Finding 1a and 1b). Adopter firms at low penetration level place more emphasis on improving process values, so process characteristics such as product complexity become significant value drivers (Finding 2a and 2b). When firms start to build a high penetration of supply chain collaboration, value is determined by the quality of relationships with trading partners. The market conditions that are favorable to building trustworthy relationships decide the outcome performance (Finding 3a and 3b). Based on those findings, we build a roadmap for superior supply chain collaboration, which is shown in figure 3.

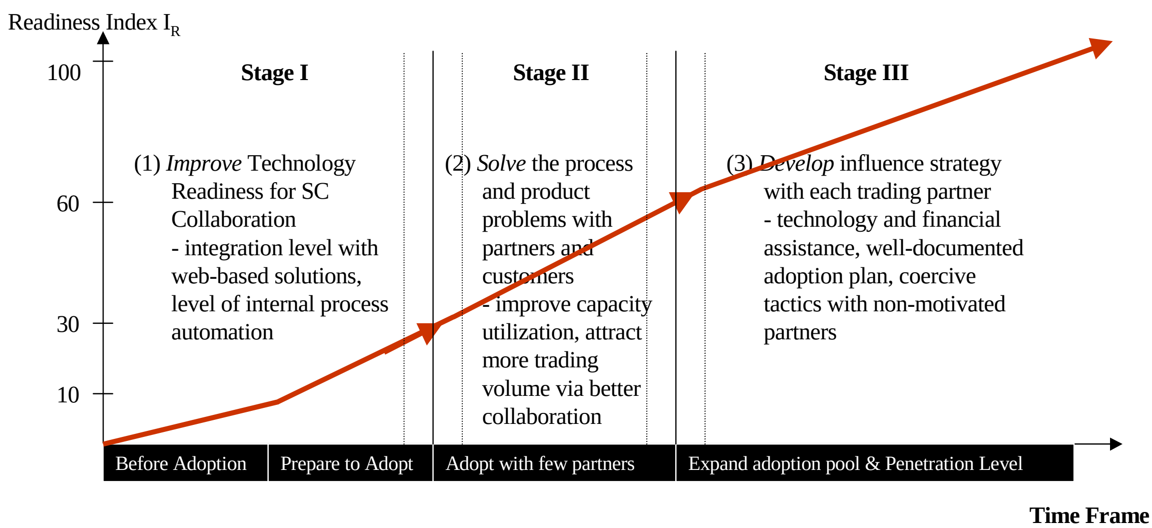

Figure 3. Roadmap for Improving SC Readiness I_R

Data Analysis

To further validate the usefulness of I_R, we apply the I_R method to verify the findings from empirical study and find the results are very similar. Figure 4 shows that firms with high technology readiness are more prepared for supply chain collaboration and the effects are more obvious in non-adopter firms than in adopter firms, suggesting that technology readiness have larger impacts on the performance of non-adopters than of adopters. The readiness between the firms at stage II and stage III is getting closer in the right end, indicating that both factors have higher performance impacts at the initial adoption stage than the stage of large scope and penetration. The results match our finding 1a that *technology readiness is more important for non-adopters to achieve greater supply chain performance*.

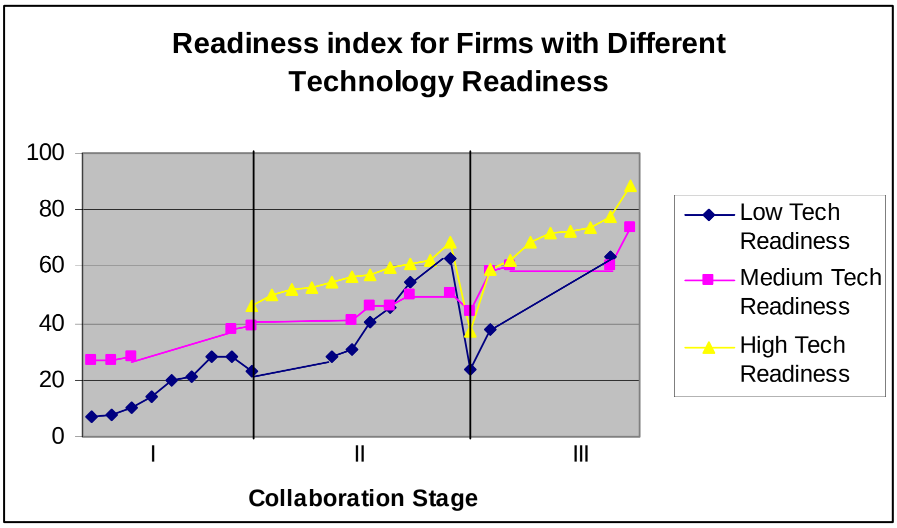

Figure 4. Readiness Index I_R for Firms with Different Technology Readiness

An attempt has also been made to compare readiness among different industries. The survey study includes cases in four industries: electronic components, semiconductors, logistics, and information technology. This cross-industry comparison may help in the identification of characteristics common to organizations in different industries. As noted in Figure 5, the four industries selected provide a distinct contrast in the value of readiness index. Four of the six cases included in IT industry have readiness over 60, while half of the cases in the industry of electronic components also have readiness over 60. Most of the cases in the semiconductor industry have readiness score between 40 and 60 and the readiness of all the cases in logistics industry is below 60. The result shows that IT industry is most ready for supply chain collaboration, followed by the industry of electronic components, semiconductor industry, and logistics industry, respectively. The finding matches the current development path of RN technology. The consortium was first developed by 40 member companies in the IT industry in 1998 and in 1999 and 2000 incorporated the members from the electronic components industry and the semiconductor industry, respectively. The rationale behind the finding is probably that the IT industry has highly mature information technology to support RN technology and that the market is also dominated by several big vendors with very high market power to lead the development. In contrast with the IT industry, the semiconductor and logistics industries are relatively fragmented with many small-sized firms. Many of these are pressured into adopting RN technology because of customers demand but they do not possess the necessary resources to integrate the technology.

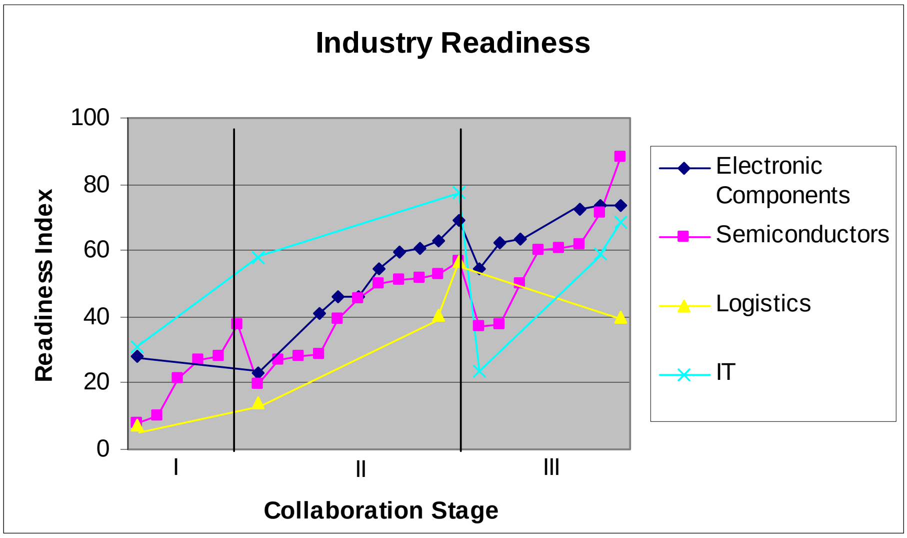

Figure 5. Readiness Index Among Four Industries

The observation in industry readiness is also consistent with the empirical result that *the market concentration and market power are positively related to the performance of supply chain collaboration* (Finding 3). Similar results can also be found when attempting to differentiate the readiness among various supply chain sectors. Figure 6 shows that buyers are most ready to implement RN technology when all cases have a readiness score over 40. Supplier firms are less ready than buyers but more ready than trading partners, while the readiness of all the trading partners are below 60. Since buyer companies in the focused industries are usually bigger than suppliers and trading partners, they are often the technology initiators that have recognized the process need for RN technology, and have reached a high level of technology readiness in a more concentrated market. Suppliers and trading partners are smaller companies with less market power in a relatively fragmented market. Some of them may perceive the needs for collaboration, while others may not.

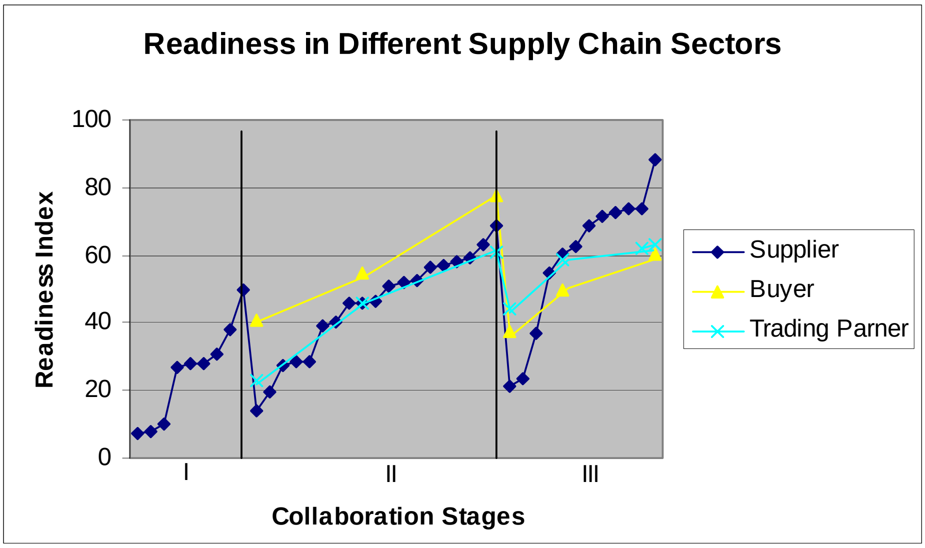

Figure 6. Readiness Index in Different Supply Chain Sectors

Numerous IOS and EDI research examples incorporate company size as an important internal organizational factor of adoption (Iskandar et al. 2001). Some research regards the greater slack resources of large firms to be a barrier to innovation and flexibility; however, others view it as a value contributor that results in increased financial capability. We measured company size by asking respondents about their annual sales in the previous year and categorized the firms into large size (above \$500 million), medium size (\$10 million to \$500 million) and small size (less than \$10 million). The I_R for each size category is shown in Figure 7 and the result indicates that size has a significant impact when companies are non-adopter firms or at the initial stage of collaboration, but the influence decreases as the firms implement higher levels of collaboration. Thus, it can be said that *size is an important factor in deciding readiness in the initial stage of adoption, but ongoing technology diffusion depends more on other supply chain and industrial characteristics.*

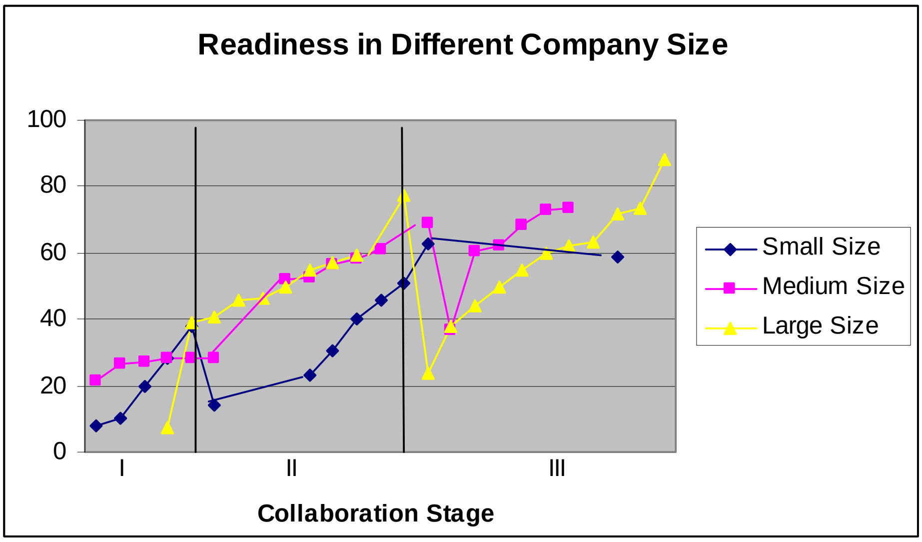

Figure 7. Readiness for Firms with Different Firm Size

In summary, this I_R index provides a general guideline for firms to develop their own readiness index to assess the value of supply chain collaboration. The data analysis shows a basic fit of our proposed theory and gives some interesting comparisons among industries and firms of different sizes and supply chain sectors.

CONCLUSION

This paper aimed to measure the supply chain collaboration readiness of firms and draw roadmaps for better performance. Empirical observation shows that the determinant conditions for deciding supply chain collaboration performance depend on a firm's development stage. Those determinant conditions such as technology readiness and process characteristics collectively determine the method of assessing the performance of supply chain collaboration. For those who choose to adopt, technology capability, product complexity, and trustworthy relationships can influence the scope of collaboration pursued. Once the adopters develop a high scope of collaboration, trading volume, market concentration and variability become favorable market conditions for conducting high penetration of sharing. By using our proposed index of supply chain readiness, denoted as I_R, non-adopters can calculate their readiness for supply chain collaboration, define their current position, and draw roadmaps for future adoption. For adopters, this approach provides information for improving readiness, and offers guidelines for making expansion decisions.

The model for calculating the readiness index is based on the 53 cases of the survey study. Although analysis of this model shows high fitness to the survey data and provides some interesting findings, further research is needed to complete the understanding of this subject. We believe that this model can form the basis of larger scale studies to (1) examine the validity and applicability of the readiness index, and (2) readjust readiness factors to fit specific scenarios. For researchers who believe other readiness factors are significant to their field could apply these value and readiness constructs in their studies and create their own model for calculating the readiness index. Large-scale cross-industry surveys can be especially appropriate for addressing this issue. Data collected from different industries would allow researchers to develop different readiness indexes for specific industrial needs, compare the differences, and finally, more objectively assess the readiness of supply chain collaboration.

Researchers could also conduct a longitudinal survey to develop the readiness index before firms implement supply chain collaboration. They can then observe the development path and evaluate the changes of readiness during different development stages. Such studies would allow researchers to assess the proposed relationship between readiness factors and value components, creating a more vigorous model for calculating the readiness index. Finally, we suggest that the model be applied in other IOS and IT as well. Additional readiness factors can be plugged into the model to make the index more generally applicable to different technologies. The modification of the readiness factors due to different technological focus should be also relevant to IT research.

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APPENDIX: CONSTRUCTION OF VARIABLES AND MEASURES

Table A1. Details of valuation constructs and measures

Valuation Construct	Description of the measures
Direct Technology Value (T1A, T1B, T2A, T2B, T3A, T3B)	(I) (Connection Benefits) Please indicate how small or large do you consider the following technology benefits as a result of implementing collaborative Its. (a) Decreases the costs to establish system interoperability with your trading partners (b) Decreases the costs to integrate IT with your company's internal systems such as ERP (II) (Platform Benefits) Please indicate how small or large do you consider the following technology benefits as a result of implementing collaborative ITs. (a) Reduces the usage of phone, fax, or email to communicate with your partners (b) Reduces the usage of EDI to communicate with your partners (III) (IT Personnel Benefits) Please indicate how small or large do you consider the following technology benefits as a result of implementing collaborative ITs. (a) Reduces IT personnel training costs (b) Reduces negotiation costs with trading partners
Direct Process Value (P1, P2A, P2B, P3)	(I) (Cycle Time Reduction) Please indicate how many man hour to process transactions was reduced as a result of implementing collaborative ITs (Information Quality) Please indicate how small or large do you consider the following process benefits as a result of implementing collaborative ITs. (a) Reduces errors (b) Improves timeliness of information (II) (Interest Benefits) Please indicate the extent to which collaborative ITs could lead to early invoicing to your customers
Indirect Technology Value (T4, T5)	(I) (Learning Effects) Please estimate how much time spent on initiating a new process standard in the future will be reduced as a result of implementing collaborative ITs (Network Effects) Please estimate how much costs of connecting your existing Collaborative ITs to new partners in the future will be reduced as a result of implementing the current collaborative ITs
Indirect Process Value (P4, P5, P6A, P6B)	(I) (Inventory Costs) Please indicate how much inventory cost was reduced as a result of implementing collaborative ITs (Capacity Utilization) Please indicate how much utilization of production lines was improved as a result of implementing collaborative ITs (Product Performance) Please indicate how small or large do you consider the following process benefits as a result of implementing collaborative ITs. (a) Reduces the time needed to transform material inputs into deliverable outputs (b) Improves production life cycle management (i.e. reduces the cost of providing service to maintain or enhance the value of the product)
Relationship Improvement (R1, R2, R3, R4A, R4B, R5)	(I) (Customer Satisfaction) Please indicate the capability of collaborative ITs to improve customer satisfaction (Customer Retention) Please indicate the capability of collaborative ITs to improve customer loyalty (Coordination Costs) Please indicate how much coordination cost with your trading partners was reduced as a result of implementing collaborative ITs (II) (Quality of Offering) Please indicate how small or large do you consider the following benefits as a result of implementing collaborative ITs. (a) Improves the quality of the inputs of your products

	(b) Improves the performance of product delivery (Better Price) Please indicate to what extent does the implementation of collaborative ITs reduce the prices of products/service that you purchase

Table A2. Measures for Technology Readiness

Valuation Construct	Description of the measures
IT capabilities (I1A, I1B, I1C)	(I) (IT Integration Level) Please indicate to what extent do you agree or disagree with the following statements about your corporate IT environment. (a) Your internal information systems (e.g. ERP or any inventory management systems) can easily integrate with Web-based solutions (b) Your internal business processes (e.g. order processing or accounts receivable) are highly automated by information systems (II) (Level of EDI Use) With your TOP trading partners, please indicate the percentage of your transactions that is processed through EDI and other similar systems (TOP trading partners are defined as those companies with whom the firm has the highest transaction dollars)
Perceived technology risks (I1D, I1E)	Please indicate to what extent do you agree or disagree with the following statements about the risks of implementing collaborative ITs (a) The technology infrastructure is too complex to integrate with other information systems in your organization (b) An effective implementation requires a lot of technical investment specific to collaborative ITs

Table A3. Measures for Readiness of Supply Chain

Valuation Construct	Description of the measures
Process Suitability (SA, SB, SC)	(I) (Complexity of Products) Please indicate the complexity of your products (II) (Transaction Volume and Frequency) For those partners that your company does business with through collaborative ITs, please indicate to what extent do you agree or disagree with the following statements about their products (a) Having relatively large demand (b) The products/production parts are required more frequently
Perceived Collaboration Risks (E1A, E1B, E1C)	(I) (Trust) Please indicate to what extent do you agree or disagree with the following statements about the risks of implementing collaborative ITs (a) Your organization trusts that confidential/proprietary information shared with your trading partners through collaborative ITs will be kept strictly confidential (b) Your partners provide you with sufficient information on implementing collaborative ITs (II) (Socio-political risks) To what extent do you agree with the statement “The responsibility between you and your partners with regard to implementing collaborative ITs (e.g. sharing payments and providing training programs) is clearly specified?
Organizational Complementarity	(I) (Technology Complementarity) To what extent do you agree with the statement “You and your partners have similar system requirements with regard to RN implementation”? (II) (Process Complementarity) To what extent do you agree with the

	statement "You and your partners have similar decision processes to handle transactions (e.g. having similar procedures to handle order change)"? (III) (Culture complementarity) To what extent do you agree with the statement "You and your partners's top management provide similar support with regard to collaborative ITs implementation"?

Table A4. Measures for Supportive Market Conditions

Valuation Construct	**Description of the measures**
Market Power	Please indicate to what extent did your partners influence your decision to adopt Collaborative ITs
Market Fragmentation	The percentage of total industry sales contributed by the largest four firms (CR4)
Market Variability	Please estimate to what extent do you predict changes in the following factors related to your partners for the next year? (a) Pricing of existing products (b) Introduction of new products

Table A5. Industry's CR4 in this survey

Industry	**US 1987 SIC**	**No. of subjects**
Communication Equipment	3661: Telephone and telegraph apparatus 3663: Radio & TV communications equipment	3663: 4 3661: 1
Semiconductor	3674: Semiconductors and related devices	24
Electronic Instrument and Controls	3679: Electronic components	12
Transportation	4213: Trucking, except local 4512: Air transportation, scheduled	5 1
Computer Hardware	3571: Electronic computers	6