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COMPETITIVE INTENSITY AND COLLABORATION: IMPACT ON FIRM GROWTH ACROSS TECHNOLOGICAL ENVIRONMENTS

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This article investigates the impact of competitive intensity and collaboration on firm growth across technological environments. I propose that competitive intensity determines the likelihood of firm collaboration, and that the interaction of competitive intensity and collaboration influences firm growth. These relationships are, in turn, moderated by industry-level technological intensity. Analyzing 1,004 firms and 378 collaborations from the manufacturing sector in Singapore, I find that firms facing high or low levels of competitive intensity collaborate less often than those facing moderate levels of competitive intensity. Industry technology intensity moderates this relationship, with a stronger inverted-U-shaped association between competitive intensity and collaboration in more technology intensive industries. Collaboration leads to higher growth for firms facing lower levels of competitive intensity than for firms facing higher levels of competitive intensity only in more technology intensive industries. In technologically less intensive industries, collaboration leads to higher growth for firms facing higher levels of competitive intensity as compared to those facing lower levels of competitive intensity. These findings have important implications for competitive and collaborative dynamics for firm growth in different technological environments.

INTRODUCTION

Collaboration allows firms to overcome resource constraints (Powell, Koput, and Smith-Doerr, 1996; Gulati, 1998; Das and Teng, 2000) and offset competitive pressures (Burgers, Hill, and Kim, 1993), thus enhancing growth prospects. It is therefore likely that the need for resources to support growth and overcome competition will influence the likelihood of collaboration and the outcomes of such collaboration. Understanding these effects will add to our knowledge of how firm heterogeneity impacts the formation and outcomes of collaboration (e.g., Ahuja, 2000; Singh and Mitchell, 2005).

Most studies of the relationship between competition and collaboration have focused on competition at the industry level, so that there has been limited firm-level analysis of competitive impacts (Demsetz, 1995). Barnett (1997) defines competitive intensity at the firm level, as the effect that a firm has on other firms' survival chances. This definition suggests that firms within an industry compete differently depending on their resources and their competitive efforts. The existence of stronger competitors is likely to increase competitive intensity and the actions that a firm takes in response. Competitive intensity is thus a fundamental characteristic at the core of industry and market structure, firm conduct, and firm performance (Bain, 1956; Demsetz, 1995).

Firms in more technology intensive industries face greater demands in technology development

Keywords: competitive intensity; collaboration; firm growth; technology intensity
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and experience more rapid changes (Dosi, 1988; Brahm, 1995), which lead to greater uncertainty and more intense competition (Perrow, 1967; Hage and Aiken, 1970; Wiggins and Ruefli, 2005). Firms facing greater competitive intensity are likely to adopt several strategies to augment their positions, including collaboration (Burgers *et al*., 1993). Collaboration also allows firms to reduce resource commitments and uncertainty associated with more technology intensive industries (Burgers *et al*., 1993). Thus, collaboration formation is likely to be contingent on the competitive intensity that a firm faces and on the technology intensity of the industry in which it operates.

Firms facing high levels of competitive intensity may find themselves less attractive partners, depriving them of collaborative opportunities to support growth. While collaboration can reduce competitive effects, they also create administrative, coordination, and information costs, which can hinder firm growth (Singh and Mitchell, 2005). Hence, competitive intensity interacts with collaboration to affect growth. The complex relationships between competitive intensity and technological environments, and their effect on collaboration formation and outcomes have not been specifically investigated. Strategy researchers have emphasized the importance to consider the opportunities and constraints faced by firms as a result of their resource base as well as the industry characteristics when investigating a firm's decisions concerning its growth (Delios and Beamish, 1999).

This study first investigates the impact of competitive intensity that a firm faces on its collaboration incidence and how industry technology intensity moderates this relationship. This is followed by an examination of the effect of the interaction between competitive intensity and collaboration on firm growth, again introducing industry technology intensity as a contingency factor. These issues are tested using data on 378 collaborations by 1,004 manufacturing firms operating in Singapore.

BACKGROUND AND HYPOTHESES DEVELOPMENT

Extensive research on the impact of competition suggests that though some degrees of competition can provide pressures for greater efficiency, high levels of competition almost always reduce firm profitability (Scherer and Ross, 1990). This literature posits that incumbent firms face identical levels of competition. More recently, Demsetz (1995) and Barnett (1997), recognizing the effects that firms' innovative efforts have on competition, introduce heterogeneity in their discussion of the different competitive dynamics incumbent firms face within an industry. Barnett (1997) suggests that a firm's competitive intensity is influenced by its ability to gain market share with the best use of its resources in the context of evolving and uncertain environments while facing challenges from other actors making similar efforts (Nelson and Winter, 1982). His definition recognizes that some firms are likely to exert greater competitive pressures and affect the viability of competitors more significantly than others. Conversely, the stronger the competitive pressures exerted by competitors, the greater the competitive intensity a firm faces.

Research in the competitive dynamics of collaboration formation has also emphasized firm heterogeneity in collaborative behavior in response to competitive pressures (Park and Zhou, 2005). Some of the justifications for collaboration in this context are greater access to resources (Das and Teng, 2000), shorter product/service development cycles (Hagedoorn, 1993), higher levels of efficiency (Lippman and Rumelt, 1982) and faster speed to market (Banbury and Mitchell, 1995) (see Barringer and Harrison (2000) for extensive discussion). Access to a partner's complementary resources allows a firm to gain from economies of scale and scope, learn and accelerate speed to market, and thus enhance competitiveness. Collaborating for market power can also weaken rivals' competitive positions by preempting their access to complementary resources possessed by potential partners (Silverman and Baum, 2002; Park and Zhou, 2005). Thus, collaboration can be used to reduce the competitive intensity that a firm faces.

Technology is widely recognized as a major contingency factor in determining firm structure and behavior (Burns and Stalker, 1961; Lawrence and Lorsch, 1967; Perrow, 1967). An industry's technology intensity is defined as the ratio of research and development (R&D) expenditure and indirect technology flows during the R&D processes to output (Organization of Economic Cooperation and Development (OECD), 1997). More technology intensive industries are characterized by significantly greater technological opportunities, more demands for multiple technological developments,

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and higher speed of technological changes (Nelson and Winter, 1982; Dosi, 1988). Incumbent firms thus face higher levels of risk and uncertainty. This is amplified by the fact that technological commitments in such industries are highly irreversible (Abernathy and Utterback, 1978) and timing of investments is highly critical (Schilling, 2002). As such, collaboration often proliferates in more technology intensive industries, as it allows firms to undertake more new product developments (Kotabe and Swan, 1995) and enhance the probability of innovative success (Goes and Park, 1997), among other benefits. The technology intensity of an industry has been found to be a moderator of the effects of firm strategy on performance (Stern and Henderson, 2004).

Competitive intensity, technology intensity, and interfirm collaboration

Firms that face low levels of competitive intensity are more likely to attract potential partners, many of whom are facing higher levels of competitive intensity, and thus will have more opportunities to collaborate and to secure favorable terms in these collaborative opportunities (Burt, 1992: 30). However, with a relatively stronger position, these firms will have less incentive to collaborate to reduce competitive intensity further. Collaborating with potentially weaker firms also risks diffusing the distinctive resources that have helped the firm establish its advantageous position in the first place. Thus, firms that face low levels of competitive intensity may hold off collaborating as potential gains may be offset by the costs and risks involved (Park and Russo, 1996; Park, Chen, and Gallagher, 2002).

Firms that face high levels of competitive intensity have a greater desire to collaborate due to their need to reduce competitive pressures. However, the desire to collaborate is a necessary but not sufficient condition for collaboration; firms must also possess the resources that make them attractive to potential partners in order to be able to access more resources through collaboration (Gulati, 1995; Eisenhardt and Schoonhoven, 1996; Dyer and Singh, 1998; Stuart, 1998; Ahuja, 2000; Park *et al*., 2002). Firms face higher levels of competitive intensity as a result of lack of distinctive resources or the inability to utilize such resources. As such, firms that face high levels of competitive intensity that are most in need of collaboration to gain access to resources may have the fewest opportunities to do so. Their incidence of collaboration is limited by the opportunities.

Firms facing moderate levels of competitive intensity have the most opportunities to collaborate as firms facing low levels of competitive intensity have less incentive to collaborate, leaving them good potential partners, while firms facing high levels of competitive intensity are not attractive partners. They also have more desire to collaborate as they have more to gain from collaboration than firms facing low levels of competitive intensity and risk being caught up by firms that face high levels of competitive intensity if they do not enhance their competitiveness through collaboration.

Hypothesis 1. There is an inverted-U-shaped relationship between competitive intensity and collaboration, such that firms facing low and high levels of competitive intensity will collaborate less often than those facing moderate levels of competitive intensity.

Significant events in more technology intensive industries, such as the introduction of a new technology, are likely to trigger more substantial changes to industry structure than in less technology intensive industries (Bettis and Hitt, 1995). As such, more technology intensive industries usually involve more intense competitive moves as incumbent firms jostle for positions in the rapidly changing environment (Brahm, 1995; Wiggins and Ruefli, 2005). The relative higher potential returns of more technology intensive industries will encourage incumbent firms to continue operations and encourage other firms to enter the industry, increasing the competition level (Brahm, 1995). Moreover, the immobility of specific assets often associated with more technology intensive industries increases commitments to the industry, hinders exits, and further increases competition (Hill and Rothaermel, 2003; Stern and Henderson, 2004).

Although the intensive use of technology by incumbent firms may also serve as an entry barrier that limits entrants (Hill and Rothaermel, 2003), this is an unstable state as such industries also permit multiple pathways to compete that result in an ever-changing competitive landscape (Rothaermel, 2000). Increasing competition will in turn escalate the speed of technological changes (Tushman and Anderson, 1986; Wade, 1995). These increase the

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opportunities and desire for collaboration as firms are entrenched in an environment characterized by competitive advantages that do not last for long periods of time.

In general, the opposite effects hold in less technology intensive industries. Technology-based competition is generally lower in these industries. Collaboration comes at a cost, and since competitive disadvantages cannot be easily neutralized by collaboration as in the case of more technology intensive industries, collaboration opportunities are relatively fewer. Even for firms facing low levels of competitive intensity, their desire to collaborate is less than those facing equivalent levels of competitive intensity in more technology intensive industries as a result of being in a more stable environment. Fewer opportunities and desires suggest that the collaboration incidence of firms will be relatively less than firms facing equivalent levels of competitive intensity in more technology intensive industries.

While the opportunities and desires to collaborate may be generally higher in more technology intensive industries, this is not evenly distributed across firms facing different levels of competitive intensity. Firms facing low competitive intensity are likely to have a substantial increase in opportunities. Yet, their desire to collaborate may not be proportionately aligned with this increase as risks of losing technological advantages that allow them to achieve low levels of competitive intensity in the first place increase with more collaboration. Firms facing high levels of competitive intensity, on the other hand, may suffer from even more limited opportunities than those facing similar levels of competitive intensity in less technology intensive industries, as other incumbent firms are wary of the dangers of partnering with these firms in the fear of losing technological advantages. Thus, in comparison to firms facing similar levels of competitive intensity in less technology intensive industries, firms facing moderate levels of competitive intensity in more technology intensive industries will have significantly more and better opportunities for collaboration. They are also likely to capitalize on these opportunities to remain competitive and thus will establish significantly more collaborations as compared to firms facing identical levels of competitive intensity within less technology intensive industries. Thus, the slopes of the inverted-U-shaped relationship between competitive intensity and collaboration are steeper in more technology intensive industries than in less technology intensive industries.

Hypothesis 2. The inverted-U-shaped relationship between competitive intensity and collaboration is stronger in more technology intensive industries than in less technology intensive industries.

Competitive intensity, interfirm collaboration, technology intensity, and firm growth

While collaboration represents a quick and cost effective way to enhance firm growth, researchers have found that there are significant limits to gains from adopting such a strategy (Hagedoorn and Schakenraad, 1994; Singh, 1997; Stuart, 2000; Singh and Mitchell, 2005). Even though collaboration also reduces development risks, there is an added element of firm risk due to the firm's reliance on partner's performance (Singh and Mitchell, 1996). Firms facing lower levels of competitive intensity have more opportunities to collaborate and are normally able to secure attractive terms in their collaboration due to stronger bargaining power. Thus, they are likely to have good options and can be highly selective in their choice of collaboration that can best enhance firm growth. Firms facing higher levels of competitive intensity, on the other hand, have relatively limited opportunities. They are more inclined to collaborate despite relatively fewer gains as competitive threat of missing collaborative opportunities is substantial (Park *et al*., 2002; Park and Zhou, 2005). It is likely that collaborations in such circumstances may have less potential growth given the limited choice of collaborative opportunities.

Hypothesis 3. Growth from collaboration is higher for firms facing lower levels of competitive intensity than for firms facing higher levels of competitive intensity.

More technology intensive industries have been found to experience higher growth rates (Stuart, 1998, 2000). This can be attributed to the many opportunities and multiple pathways to compete and succeed in such industries, suggesting that the dynamics of competitive intensity-collaboration on firm growth may differ across industries with different technology intensities. Aghion *et al*. (2001)

argue that at the industry level, an increase in market competition will lead to growth as the usual Schumpeterian effect of intense competition is almost always outweighed by the increased incentive for firms to innovate to escape competition. Hence, there are significant greater opportunities to collaborate within more technology intensive industries (Hagedoorn, 1993). Such opportunities provide firms with a bigger and better selection of high-growth collaborative opportunities for firms facing lower levels of competitive intensity. In less technology intensive industries, firms facing lower levels of competitive intensity do not have similar opportunities. The choice of high-growth collaboration is lesser due to greater environmental stability and less technological competition.

On top of being unattractive partners like firms facing similar levels of competitive intensity in less technology intensive industries, firms facing higher levels of competitive intensity in more technology intensive industries face the added element of fear of technological leakage by potential partners. As such, their opportunities to collaborate are even more limited and restrictive in terms of growth potential. Thus, the gap between the growth from collaboration for firms facing higher and lower levels of competitive intensity is larger in more technology intensive industries.

Hypothesis 4: The higher growth from collaboration for firms facing lower levels of competitive intensity than for firms facing higher levels of competitive intensity is greater in more technology intensive industries than in less technology intensive industries.

DATA AND VARIABLES

Data

The hypotheses are tested with firms operating in the Singapore manufacturing sector, which hosts more than 4,000 multinational corporations, embodies significant technological variation, and has experienced significant interfirm collaboration. This study focuses on the 11 major industries that generate the most value-added within the sector (Ministry of Trade and Industry, 1996: 54). These are 'paints, pharmaceuticals and other chemical products,' 'petroleum products,' 'electronic products,' 'machinery except electrical and electronic,' 'electrical machinery, apparatus and appliances,' 'industrial chemicals and gases,' 'plastic products,' 'fabricated metal products,' 'transport equipment,' 'printing and publishing,' and 'food.' Background information of firms is collected from the *Key Business Directory of Singapore* (Dun & Bradstreet, 1992/1993–1997/1998), which lists firms that have more than S$12million (US$7.4million) in sales and/or more than 50 employees. To allow for lag effects for firm growth, I focus on collaborative activities for the period 1994–1996. In total, 1,004 firms are listed at least once in the directory in the period 1994–1996. Of these, 883 firms appeared in all three years, 58 firms appeared in two of the years and 63 firms appeared once. This resulted in a pooled cross-sectional sample of 2,828 firm-years. Collaboration data related to the sample firms are then collected by screening through business newspaper articles in the only two English language newspapers in Singapore, *The Straits Times* and *The Business Times*, during the period of the study. The newspaper articles are then content-analyzed to identify reports of collaboration. This process results in 378 cases of collaboration for analysis.

Variables

Firm growth

Following prior research (Podolny, Stuart, and Hannan, 1996; Stuart, 2000), I model firm growth as

$$S_{i,t+1} = S_{i,t} \exp^{(\pi' x_{it})\varepsilon}$$

where $S_{i,t}$ is the sales of firm i at time t and X_{it} is a covariate matrix. The first difference of log sales is estimated using ordinary least square regression for the tests on firm growth.

Collaboration

I define collaboration as voluntary cooperation between firms involving exchange, sharing, or co-development of products, technologies, or services (Gulati, 1998). The number count of collaboration agreements established by a firm in each year is used as the measure.

Competitive intensity

For each firm, I gather information about the business lines in which it engages. For each of

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these business lines, I track data relating to the product market size (in terms of sales) and the number of competing firms within the product market. These figures are taken from the *Report of the Census of Industrial Production* for the years 1994–1996 (Economic Development Board, 1994–1996). Next I calculate the average competition faced by each firm in each of its participating product markets by dividing the product market size by the number of competing firms. Competitive intensity that a firm faces is the log of the total sum of average competition it faces in all its participating product markets. This measurement takes into consideration that firms within the same industry can face different levels of competition as they are competing in different product markets.

Technology intensity

I adopt the OECD (1997) measure of industry technology intensity as a moderating variable. The classification of industries as high, medium-high, medium-low, and low technology intensive is based on the ratio of R&D expenditure and embodied technology to output. Embodied technology refers to the indirect technology flows during the R&D processes, beyond the direct amount of R&D conducted. Using this criterion, 'paints, pharmaceuticals and other chemical products,' 'petroleum products,' and 'electronic products' are classified as high technology intensive; 'machinery except electrical and electronic,' 'electrical machinery, apparatus and appliances,' and 'industrial chemicals and gases' are classified as medium-high technology intensive; 'plastic products,' 'fabricated metal products,' and 'transport equipment' are classified as medium-low technology intensive; and 'printing and publishing' and 'food' are classified as low technology intensive.

Though Singapore is not part of the OECD, the use of the OECD classification is appropriate as Singapore approaches OECD countries on most measures of wealth, income, industrial strength, competitiveness, and institutional development (World Economic Forum, 1999). In addition, the technological behaviors of firms in Singapore mirror those of the industrialized nations in areas such as technology strategy, sourcing and cooperation, and R&D spending (International Institute for Management Development, 1996), partly because of the very large presence of multinational corporations in the country. In fact, Singapore's rapid progress has been based on extensive technological upgrading and on major new entry and investments by domestic and foreign firms.

Control variables

Firm size is used to account for the greater resources and choices available to larger firms, for these firms' greater ability to invest in technology and innovation, and for potential scale advantages (Scherer and Ross, 1990). Three indicator variables categorize firms as being large (greater or equal to 500 employees), medium, or small (fewer than 100 employees). Firm age (in years, from establishment of operations in Singapore) and the number count of lines of business that a firm participated in are used to control for firm viability (Barnett, 1997) and performance.

An indicator variable records whether a firm is publicly listed, as such firms have greater access to resources (Durand and Vargas, 2003). Three indicator variables represent whether the firm is of Triad origin (Japan, Europe, and the United States), Asian origin (less Japan and Singapore) or Singapore origin. These variables control for the varying resources, experience, and skills that are available to the firm. Unobserved heterogeneity may occur in pooled cross-sectional data, when there is more than one observation per firm in the analysis. This will result in biased estimates as the observations are not independent of each other (Petersen and Koput, 1991). This can be addressed by controlling for firm-specific error terms that are fixed over time (fixed-effects model) or vary over time (random-effects model). Dummy variables represent the industry in which the firm resides, and is introduced to control for fixed effects. Table 1 provides the summary statistics and the correlation matrix for all variables used in this study.

Table 2 shows the descriptive statistics of the key variables used in this study. It lists the mean, standard deviation, minimum and maximum values of firm growth, collaboration and competitive intensity within each industry and across the different industry technology intensities. The table shows that firms in medium-low technology intensive industries tend to have lower growth rates. Yet interestingly enough, they have the highest average

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Table 1. Correlation matrix (N = 2828)

	Variable	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(1)	Firm growth	0.02	0.20																
(2)	Collaboration	0.13	0.72	−0.03															
(3)	Competitive intensity	3.65	1.57	0.00	0.09														
(4)	High tech intensity	0.26	0.44	0.02	−0.05	0.42													
(5)	Med-high tech intensity	0.27	0.44	0.01	0.00	0.18	−0.37												
(6)	Med-low tech intensity	0.32	0.47	−0.04	0.04	−0.36	−0.41	−0.42											
(7)	Low tech intensity	0.14	0.35	0.01	0.01	−0.27	−0.25	−0.25	−0.28										
(8)	Firm age	16.05	9.45	−0.01	0.05	−0.04	−0.02	−0.08	0.01	0.12									
(9)	Firm is large in size	0.15	0.35	0.00	0.19	0.31	0.17	−0.01	−0.11	−0.05	0.11								
(10)	Firm is medium in size	0.47	0.50	0.01	−0.01	−0.07	−0.05	−0.05	0.08	0.01	0.06	−0.39							
(11)	Firm is small in size	0.38	0.49	−0.01	−0.12	−0.16	−0.07	0.05	0.00	0.02	−0.14	−0.32	−0.74						
(12)	Number of business lines	1.35	0.65	0.01	0.05	0.26	−0.08	0.03	−0.09	0.18	0.17	0.06	0.06	−0.11					
(13)	Firm is publicly listed	0.07	0.26	−0.03	0.42	0.04	−0.03	−0.01	−0.00	0.05	0.12	0.22	0.01	−0.18	0.05				
(14)	Firm is of Triad origin	0.37	0.48	0.03	−0.11	0.19	0.12	0.17	−0.17	−0.14	0.02	0.15	0.01	−0.12	−0.00	−0.15			
(15)	Firm is of Asian origin	0.04	0.20	0.02	−0.02	−0.02	0.02	−0.03	−0.02	0.04	0.00	−0.01	−0.04	0.04	0.01	0.00	−0.16		
(16)	Firm is of Singaporean origin	0.59	0.49	−0.04	0.11	−0.18	−0.12	−0.15	0.17	0.12	−0.03	−0.14	0.00	0.10	0.00	0.15	−0.92	−0.25	
(17)	Paints, pharmaceuticals & other chemical products	0.07	0.25	0.02	−0.04	0.01	0.44	−0.16	−0.18	−0.11	0.11	−0.08	−0.02	0.09	−0.05	−0.03	0.07	0.05	−0.09
(18)	Petroleum products	0.01	0.12	−0.00	0.01	0.22	0.20	−0.07	−0.08	−0.05	0.07	0.05	0.00	−0.04	−0.02	0.00	0.02	−0.02	−0.01
(19)	Electronic products	0.18	0.39	0.01	−0.03	0.40	0.80	−0.29	−0.33	−0.20	−0.12	0.23	−0.04	−0.13	−0.05	−0.01	0.08	−0.00	−0.08
(20)	Machinery except electrical & electronic	0.17	0.37	−0.01	0.03	0.19	−0.27	0.73	−0.31	−0.18	−0.09	0.02	−0.04	0.02	−0.01	0.05	0.08	−0.04	−0.06

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Table 1. (*Continued*)

	Variable	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(21)	Electrical machinery, apparatus & appliances	0.06	0.24	0.03	−0.04	0.00	−0.15	0.42	−0.18	−0.11	−0.01	0.03	−0.01	−0.01	0.06	−0.06	0.10	0.02	−0.11
(22)	Industrial chemicals & gases	0.04	0.20	−0.00	−0.02	0.04	−0.13	0.35	−0.15	−0.09	0.01	−0.08	−0.02	0.08	0.02	−0.04	0.11	−0.02	−0.10
(23)	Plastic products	0.11	0.31	−0.03	−0.03	−0.28	−0.21	−0.21	0.51	−0.14	−0.01	−0.10	0.06	0.01	−0.13	−0.03	−0.08	−0.04	0.09
(24)	Fabricated metal products	0.14	0.35	0.01	−0.01	−0.17	−0.24	−0.25	0.58	−0.16	0.02	−0.11	0.05	0.02	0.07	−0.02	−0.05	0.06	0.02
(25)	Transport equipment	0.07	0.26	−0.04	0.12	−0.09	−0.17	−0.17	0.41	−0.12	0.01	0.05	−0.00	−0.03	−0.11	0.06	−0.14	−0.06	0.16
(26)	Printing & publishing	0.07	0.25	0.02	−0.01	−0.27	−0.16	−0.17	−0.19	0.66	0.04	−0.05	0.06	−0.02	0.06	0.00	−0.13	−0.00	0.13
(27)	Food	0.08	0.26	−0.01	0.02	−0.10	−0.17	−0.17	−0.20	0.70	0.12	−0.02	−0.04	0.05	0.17	0.06	−0.06	0.05	0.04
(28)	Year 1994	0.33	0.47	0.02	0.05	−0.02	−0.00	−0.00	0.00	0.00	−0.07	−0.01	0.01	−0.01	0.01	0.00	−0.00	0.00	0.00
(29)	Year 1995	0.33	0.47	0.01	−0.01	0.00	0.00	−0.00	−0.00	0.00	0.01	0.00	0.00	−0.00	−0.01	−0.01	−0.00	0.01	0.00
(30)	Year 1996	0.34	0.47	−0.03	−0.04	0.02	0.00	0.00	0.00	−0.01	0.06	0.01	−0.01	0.01	−0.00	0.00	0.01	−0.01	−0.01

	Variable	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)
(18)	Petroleum products	−0.03												
(19)	Electronic products	−0.13	−0.06											
(20)	Machinery except electrical & electronic	−0.12	−0.05	−0.21										
(21)	Electrical machinery, apparatus & appliances	−0.07	−0.03	−0.12	−0.11									
(22)	Industrial chemicals & gases	−0.06	−0.02	−0.10	−0.09	−0.05								
(23)	Plastic products	−0.09	−0.04	−0.17	−0.16	−0.09	−0.07							
(24)	Fabricated metal products	−0.11	−0.05	−0.19	−0.18	−0.10	−0.08	−0.14						
(25)	Transport equipment	−0.07	−0.03	−0.13	−0.13	−0.07	−0.06	−0.10	−0.11					
(26)	Printing & publishing	−0.07	−0.03	−0.13	−0.12	−0.07	−0.06	−0.09	−0.11	−0.08				
(27)	Food	−0.08	−0.03	−0.14	−0.13	−0.07	−0.06	−0.10	−0.11	−0.08	−0.08			
(28)	Year 1994	0.00	0.00	−0.01	0.00	−0.01	−0.00	0.00	−0.00	0.00	0.00	0.00		
(29)	Year 1995	0.00	−0.00	0.00	−0.00	−0.00	0.00	−0.01	−0.00	0.00	0.00	0.00	−0.50	
(30)	Year 1996	−0.00	0.00	0.00	−0.00	0.01	−0.00	0.00	0.00	−0.00	−0.00	−0.01	−0.50	−0.50

$|r| > 0.031 - p < 0.10$; $|r| > 0.037 - p < 0.05$; $|r| > 0.048 - p < 0.01$; $|r| > 0.064 - p < 0.001$

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Table 2. Descriptive statistics

Industry tech intensity	# of obs.	Growth				Collaboration				Competitive intensity			
		Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
High													
Paints, pharmaceuticals & other chemical products	185	0.031	0.164	−0.861	0.675	0.027	0.243	0	3	3.714	1.118	0.958	5.912
Petroleum products	38	0.018	0.161	−0.753	0.308	0.211	0.622	0	3	6.595	0.244	6.385	7.005
Electronic products	522	0.025	0.214	−1.686	0.778	0.084	0.425	0	5	4.972	1.015	2.892	7.456
High overall	*745*	*0.026*	*0.200*	*−1.686*	*0.778*	*0.077*	*0.403*	*0*	*5*	*4.742*	*1.229*	*0.958*	*7.456*
Medium-high													
Machinery except electrical & electronic	472	0.017	0.243	−2.401	0.755	0.184	0.950	0	10	4.306	2.102	0.883	7.936
Electrical machinery, apparatus & appliances	175	0.044	0.153	−1.105	0.504	0.034	0.282	0	3	3.655	1.414	1.002	7.444
Industrial chemicals & gases	121	0.015	0.210	−1.894	0.738	0.083	0.420	0	3	3.932	0.758	2.000	7.023
Medium-high overall	*768*	*0.023*	*0.220*	*−2.401*	*0.755*	*0.134*	*0.777*	*0*	*10*	*4.099*	*1.825*	*0.883*	*7.936*
Medium-low													
Plastic products	307	0.002	0.184	−1.604	0.557	0.062	0.517	0	7	2.386	0.539	1.576	6.139
Fabricated metal products	393	0.022	0.159	−0.995	0.654	0.120	0.517	0	11	3.000	0.864	1.833	7.140
Transport equipment	207	−0.007	0.254	−1.742	0.704	0.449	1.389	0	11	3.166	0.523	2.385	4.835
Medium-low overall	*907*	*0.009*	*0.193*	*−1.742*	*0.704*	*0.175*	*0.896*	*0*	*11*	*2.830*	*0.767*	*1.576*	*7.140*
Low													
Printing & publishing	194	0.034	0.164	−1.321	0.735	0.098	0.563	0	6	2.106	1.030	0.219	5.334
Food	214	0.011	0.179	−1.530	0.675	0.187	0.622	0	5	3.082	1.354	1.049	5.638
Low overall	*408*	*0.022*	*0.172*	*−1.530*	*0.735*	*0.145*	*0.596*	*0*	*6*	*2.618*	*1.304*	*0.219*	*5.638*
Total	2828	0.019	0.200	−2.401	0.778	0.134	0.719	0	11	3.648	1.573	0.219	7.936

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number of collaborations established. The competitive intensities of high and medium-high technology intensive industries are higher than those of medium-low and low technology intensive industries. As expected, these industries also have a higher dispersion of competitive intensity within the industries.

Methods

I use fixed-effects Poisson regression analysis to test Hypotheses 1 and 2 as the dependent variable is the number count of collaboration. Fixed-effects ordinary least square linear regression analysis is used for testing Hypotheses 3 and 4 as the dependent variable firm growth is a continuous variable.

RESULTS

Table 3 shows the Poisson regression results for the effect of competitive intensity on collaboration. Model 1 shows the baseline model while Model 2 shows the full model for the effect of competitive intensity on collaboration using the full sample. The competitive intensity variable is positive and significant while its squared term is negative though not significant. The change in explanatory power in Model 2 over Model 1 is significant. Thus, Hypothesis 1 is partially supported.

To test Hypothesis 2, I split the sample into the four technology intensity groups. Models 3 to 10 present the results of these subsample regression models. The inverted-U-shaped relationship between competitive intensity and collaboration is evident in all but the low technology intensive industries. Significant coefficients in both the competitive intensity and the competitive intensity squared terms are only found in more technology intensive industries. This suggests that the inverted-U-shaped relationship between competitive intensity and collaboration is stronger in more technology intensive industries than in less technology intensive industries, supporting Hypothesis 2.

In order to get a clearer picture of the effect of competitive intensity on collaboration, I look further at the critical values of competitive intensity in the significant models in Table 3. For the full sample model, based on the coefficients of both the competitive intensity ($\beta = 0.66$, $p = 0.005$) and competitive intensity squared terms ($\beta = -0.03$, $p = 0.114$), the critical value of competitive intensity is at 1.9938. That is, the incidence of collaboration will increase with increasing competitive intensity until this point, after which it will decline. The percentage of observations that is below this value is 9.5 percent. For the sample of firms in medium-high technology intensive industries, in which both the competitive intensity ($\beta = 1.41$, $p = 0.014$) and competitive intensity squared ($\beta = -0.11$, $p = 0.044$) terms are significant, the critical value of competitive intensity is 4.5723. The percentage of observations that is below this value is 70.2 percent. For the sample of firms in medium-low technology intensive industries in which the competitive intensity term is significant ($\beta = 0.98$, $p = 0.053$) but the competitive intensity squared term is not ($\beta = -0.03$, $p = 0.347$), the critical value of competitive intensity is 2.7458. The percentage of observations that is below this value is 50.4 percent. As seen here, the inflection point for different samples deviates, partially a reflection of the varying degrees of dispersion of competitive intensity.

Older firms have less collaboration than younger ones. Established firms will have systems in place that make them engage in fewer collaborations. Younger firms on the other hand, tend to collaborate more for access to resources for growth. Large- and medium-sized firms tend to collaborate more often than small firms. The nature of businesses for large- and medium-sized firms may impose additional managerial and operational demands, driving them to collaborate more to access partners' resources. Publicly listed firms have higher collaboration incidence than their non-publicly listed counterparts. Listed firms are more credible as their performances are more transparent. They also have better access to capital. These make them attractive partners for other firms. Firms of Triad and Asian origin form fewer collaborations than Singapore firms. The size of the Singapore market and the resource limitations of Singapore firms suggest that collaboration is a good means by which these firms can expand. Triad subsidiaries, however, tend to have better access to resources through their parents' network connections and thus have less need to collaborate. The industry and year dummies also show varying effects on collaboration.

Table 4 presents results of the test of the impact of competitive intensity and collaboration on firm

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Table 3. Poisson regression results for competitive intensity on interfirm collaboration

Variable	Full sample		High tech intensity		Medium-high tech intensity		Medium-low tech intensity		Low tech intensity	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Intercept	−3.57***	−5.01***	−3.99***	−10.17*	−4.15***	−7.95***	−2.64***	−5.22***	−2.57***	−2.29**
	(0.32)	(0.60)	(0.56)	(4.88)	(0.64)	(1.67)	(0.48)	(1.19)	(0.46)	(0.89)
Firm age	−0.02**	−0.01*	−0.04*	−0.04*	0.01	0.01	−0.02+	−0.00	−0.03**	−0.03**
	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Firm is large in size	1.94***	1.58***	2.02***	2.09***	2.53***	1.96***	1.69***	1.42**	1.74***	1.62***
	(0.24)	(0.24)	(0.53)	(0.53)	(0.51)	(0.55)	(0.48)	(0.48)	(0.49)	(0.52)
Firm is medium in size	1.31***	1.21***	0.71+	0.80+	1.84***	1.81***	1.61***	1.41***	0.21	0.28
	(0.23)	(0.23)	(0.52)	(0.53)	(0.48)	(0.50)	(0.44)	(0.44)	(0.47)	(0.47)
Number of business lines	0.30***	0.10	0.72***	0.58**	0.30*	0.18	−0.07	−0.40*	0.34**	0.18
	(0.07)	(0.08)	(0.20)	(0.23)	(0.14)	(0.15)	(0.15)	(0.17)	(0.13)	(0.17)
Firm is publicly listed	2.40***	2.43***	2.39***	2.44***	2.51***	2.33***	2.75***	2.76***	1.78***	1.86***
	(0.13)	(0.13)	(0.32)	(0.33)	(0.26)	(0.26)	(0.23)	(0.23)	(0.40)	(0.40)
Firm is of Triad origin	−1.12***	−1.10***	−0.67*	−0.70*	−1.12***	−1.09***	−2.03***	−2.07***	−2.18*	−2.17*
	(0.19)	(0.19)	(0.33)	(0.33)	(0.32)	(0.33)	(0.59)	(0.59)	(1.02)	(1.02)
Firm is of Asian origin	−0.73*	−0.61*	−1.73*	−1.76*	−17.58	−15.47	0.15	0.09	−1.46+	−1.36+
	(0.35)	(0.35)	(0.81)	(0.85)	(6510.58)	(2607.34)	(0.47)	(0.49)	(1.02)	(1.02)
Paints, pharmaceuticals & other chemical products	−0.67+	−1.14*	−0.15	0.22						
	(0.49)	(0.49)	(0.51)	(0.52)						
Petroleum products	0.64+	−0.59+	1.36***	1.10*						
	(0.39)	(0.44)	(0.43)	(0.49)						
Electronic products	−0.44*	−1.05***								
	(0.24)	(0.25)								
Machinery except electrical & electronic	0.15	−0.60*			−0.29	−0.07				
	(0.22)	(0.28)			(0.37)	(0.39)				
Electrical machinery, apparatus & appliances	−0.58+	−1.10**			−1.07*	−1.06*				
	(0.45)	(0.45)			(0.52)	(0.52)				

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Table 3. (*Continued*)

Variable	Full sample		High tech intensity		Medium-high tech intensity		Medium-low tech intensity		Low tech intensity	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Industrial chemicals & gases	0.52^{+}	0.03								
	(0.36)	(0.37)								
Plastic products	−0.62*	−0.33					−1.35***	−0.74**		
	(0.29)	(0.30)					(0.28)	(0.31)		
Fabricated metal products	−0.11	−0.04					−0.74***	−0.62**		
	(0.23)	(0.24)					(0.23)	(0.23)		
Transport equipment	0.63***	0.68***								
	(0.20)	(0.21)								
Printing & publishing	−0.83**	−0.45^{+}							−0.88**	−0.88**
	(0.30)	(0.31)							(0.33)	(0.36)
Year is 1995	−0.30**	−0.31**	−0.80*	−0.77*	0.01	0.02	−0.48**	−0.49**	−0.08	−0.07
	(0.12)	(0.12)	(0.35)	(0.35)	(0.22)	(0.23)	(0.19)	(0.19)	(0.30)	(0.30)
Year is 1996	−0.54***	−0.54***	−0.73*	−0.70*	−0.72**	−0.67**	−0.44*	−0.43*	−0.52^{+}	−0.52^{+}
	(0.13)	(0.13)	(0.33)	(0.34)	(0.27)	(0.27)	(0.19)	(0.19)	(0.33)	(0.34)
Competitive intensity		0.66**		2.15		1.41*		0.98^{+}		−0.29
		(0.25)		(1.87)		(0.64)		(0.61)		(0.58)
Competitive intensity^{2}		−0.03		−0.17		−0.11*		−0.03		0.08
		(0.03)		(0.18)		(0.06)		(0.08)		(0.09)
Deviance	1237.37	1182.98	229.22	223.64	337.89	309.05	449.30	414.48	153.68	150.86
d.f.	19	21	11	13	11	13	11	13	10	12
Change in deviance over previous model		54.39***		5.58^{+}		28.84***		34.82***		2.82
Number of firm years	2828	2828	745	745	768	768	907	907	408	408

One-tailed tests. $^{+}$ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. Standard errors are in parentheses.

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Table 4. Linear regression results of competitive intensity and interfirm collaboration on firm growth

Variable	Full sample		High tech intensity		Medium-high tech intensity		Medium-low tech intensity		Low tech intensity	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Intercept	0.05^{+}	0.07*	−0.01	−0.38**	0.00	−0.02	0.20*	0.21*	−0.00	−0.00
Firm age	−0.01	−0.01	−0.07*	−0.07*	−0.00	−0.01	0.04	0.03	−0.03	−0.03
Firm is large in size	0.01	0.01	0.03	0.03	0.05	0.05	0.01	−0.01	−0.04	−0.02
Firm is medium in size	0.02	0.02	0.02	0.02	0.03	0.04	−0.00	−0.01	0.08^{+}	0.08^{+}
Number of business lines	0.01	0.01	−0.00	0.01	0.03	0.03	0.08*	0.08*	−0.06	−0.07
Firm is publicly listed	−0.03	−0.05*	−0.08^{+}	−0.06	0.04	0.06	−0.05	−0.15**	−0.04	−0.03
Firm is of Triad origin	0.02	0.03	0.02	0.03	−0.02	−0.02	0.04	0.05^{+}	0.04	0.03
Firm is of Asian origin	0.02	0.02	0.07*	0.06^{+}	−0.00	−0.00	0.00	0.01	0.01	0.01
Paints, pharmaceuticals & other chemical products	0.03	0.03	0.06	0.05						
Petroleum products	0.01	0.01	−0.00	0.01						
Electronic products	0.03	0.03								
Machinery except electrical & electronic	0.01	0.00			−0.00	−0.00				
Electrical machinery, apparatus & appliances	0.04^{+}	0.04^{+}			0.05	0.04				
Industrial chemicals & gases	0.01	0.01								

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Table 4. (*Continued*)

Variable	Full sample		High tech intensity		Medium-high tech intensity		Medium-low tech intensity		Low tech intensity	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Plastic products	−0.02	−0.02					−0.06	−0.03		
Fabricated metal products	0.02	0.01					0.01	0.04		
Transport equipment	−0.02	−0.03								
Printing & publishing	0.02	0.02							0.00	−0.01
Year is 1995	−0.01	−0.01	−0.05	−0.04	0.02	0.02	−0.05	−0.04	0.07^{+}	0.07^{+}
Year is 1996	-0.04^{*}	-0.04^{+}	−0.04	−0.03	-0.10^{**}	-0.10^{**}	-0.06^{+}	−0.05	0.14^{**}	0.14^{**}
Competitive intensity	-0.15^{+}	-0.22^{*}	0.09	0.98^{**}	0.05	0.14	-0.49^{*}	-0.52^{**}	0.21	0.23
Competitive intensity^2	0.13	0.19^{*}	−0.02	-0.82^{**}	−0.07	−0.15	0.41^{*}	0.42^{*}	-0.34^{+}	-0.36^{+}
Collaboration	0.01	0.07^{*}	-0.07^{+}	-0.29^{**}	−0.01	−0.10	0.03	0.31^{**}	0.10	0.05
Competitive intensity × Collaboration		-0.53^{**}		3.50^{***}		0.46		-0.73^{*}		−0.04
Competitive intensity^2 × Collaboration		0.49^{**}		-3.30^{***}		−0.40		0.53^{+}		0.08
F-Statistic	1.02	1.21	1.57^{+}	2.24^{**}	1.06	0.95	1.19	1.55^{+}	1.61^{+}	1.41
d.f.	22	24	14	16	14	16	14	16	13	15
Change in F-Statistic over previous model		3.257^{*}		6.722^{**}		0.153		3.979^{*}		0.124
Number of firm years	2828	2828	745	745	768	768	907	907	408	408

The coefficients are standardized estimates. One-tailed tests. $^{+}\ p < 0.10$; $^{*}\ p < 0.05$; $^{**}\ p < 0.01$; $^{***}\ p < 0.001$

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growth. Model 1 is the baseline model and Model 2 adds the interaction terms of competitive intensity and collaboration in the full sample model. I substitute the predicted value from Model 2 in Table 3 for the true value of collaboration in this regression to avoid correlation with the error term. The inclusion of the interaction terms significantly improves the explanatory power of the model. A negative sign for the term competitive intensity × collaboration and a positive sign for the term competitive intensity^2 × collaboration suggest that firms facing lower levels of competitive intensity will have lesser growth from collaboration as compared to firms facing higher levels of competitive intensity. Thus, Hypothesis 3 is not supported.

To test Hypothesis 4, I split the sample into the four technology intensity groups. The results are presented in Models 3 to 10 in Table 4. It is evident that firms facing lower levels of competitive intensity will have greater growth from collaboration as compared to firms facing higher levels of competitive intensity only in the case of high technology intensive industries. Thus, Hypothesis 4 is supported. The results also show that in medium-low technology intensive industries, firms facing lower levels of competitive intensity actually have lesser growth from collaboration as compared to firms facing higher levels of competitive intensity.

DISCUSSION AND CONCLUSION

This study investigates the impact of competitive intensity and collaboration on firm growth across technological environments. Specifically, it examines the impact of competitive intensity on the formation of firm collaboration, and of the interaction of competitive intensity and collaboration on firm growth. These relationships are predicted to be moderated by industry-level technological intensity. Results largely support predictions of significant association between competitive intensity and collaboration and of their interaction on firm growth. Industry technology intensity is found to have an important influence on these results.

Firms face low levels of competitive intensity as a result of possessing distinctive resources and being more able to utilize resources, making them more attractive potential partners and hence greater collaborative opportunities. However, collaboration comes with administrative and managerial costs (e.g., Singh, 1997). There is also a risk of losing proprietary technology and information. This suggests that firms with greater opportunities may not necessarily collaborate more often as there is less incentive to do so. Firms facing high levels of competitive intensity have greater pressures to collaborate to reduce competition. However, they are not attractive potential partners and hence are unable to engage in the increased collaboration that they desire (Eisenhardt and Schoonhoven, 1996; Park *et al*., 2002). Firms facing moderate levels of competitive intensity have both greater pressures and opportunities to collaborate and hence will collaborate more often.

The inverted-U-shaped relationship between competitive intensity and collaboration result enhances our understanding of competitive dynamics of collaboration (Park and Zhou, 2005). Much of the literature on competition is grounded in industrial economics and measured at the industry level. While firm-level competition has been conceptually discussed (e.g., Demsetz, 1995; Barnett, 1997), little empirical evidence exists. This study advances empirical research on competition at the firm level. The resource-based view suggests that the heterogeneous resources that a firm possesses result in favorable strategic and social positions that affect its ability to collaborate (Eisenhardt and Schoonhoven, 1996). This perspective often underemphasizes the role of other players in shaping a focal firm's behavior (Park and Zhou, 2005). The finding here extends this view to the firm-level competition that a firm faces. The competitive intensity that a firm faces is a result of its lack of resources, or inability to utilize the resources, and has implications for its ability to collaborate. This finding also supports and provides further evidence for the arguments that collaboration is a result of the inducement and opportunities to collaborate (e.g., Ahuja, 2000). Firms not reacting to increased competitive intensity may find themselves facing even higher levels of competitive intensity, which can further constrain their ability to collaborate. The ability to collaborate is a valuable option and any collaboration can be a signal of credibility for the firm. Thus, responding to competition to avoid being disadvantaged must also be a priority.

I also find support that the inverted-U-shaped relationship between competitive intensity and collaboration is stronger in more technology intensive industries than in less technology intensive industries. More technology intensive industries are

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characterized by greater uncertainties and an ever changing competitive landscape, which translate to shorter competition cycles and shorter time to react to changes. Multiple pathways to compete complicate competitive dynamics within more technology intensive industries (Rothaermel, 2000). Firms in such industries are faced with the added element of technological leakage. Firms that have achieved the position of facing low levels of competitive intensity may have done so with their distinctive technological advantages. Establishing more collaboration will increase technological risks. Firms that face high levels of competitive intensity will face significant difficulties to collaborate as opportunities are limited due to this same fear of technological leakage of potential partners. These dynamics provide firms facing moderate levels of competitive intensity with significantly added collaborative opportunities to capitalize on.

This result is consistent with contingency theory that has emphasized technology as a contingent factor that influences the structure and behavior of organizations (e.g., Perrow, 1967). Separately, competition (Brahm, 1995) and collaboration (Hagedoorn, 1993) have been shown to be more intense in more technology intensive industries. This study links competition and collaboration dynamics within industry, extending competition to the firm level. Additional analyses suggest that these differences also include the inflection point of the nonlinear competitive intensity-collaboration relationship. A firm facing the same levels of competitive intensity in different technology intensive industries will face different opportunities and desires to collaborate resulting in different collaboration incidence. Thus, firm-level competitive and collaborative dynamics differ among incumbent firms across different technological environments.

Firms facing lower levels of competitive intensity have greater growth from collaboration as compared to firms facing higher levels of competitive intensity in more technology intensive industries. As firms that face lower levels of competitive intensity have less incentive but more choices to collaborate, they will be more selective in their choice of collaborative activities. Opportunities to collaborate are also enhanced by the generally higher levels of competition and the potential multiple pathways in which firms can compete. These are likely to result in collaborations that offer greater growth prospects for the firm. On the other hand, firms that face higher levels of competitive intensity have relatively limited opportunities, and thus collaborations that they engage in will be limited to what is available, which may have less growth prospects due to the firms' relatively unattractive positions. In more technology intensive industries, this effect is even more evident as potential partners are also wary of potential technological leakage when partnering with these firms. Thus, firms facing higher levels of competitive intensity are likely to compromise the suitability of a potential partner in an attempt to collaborate, as failure to collaborate can potentially result in further disadvantages that will be more difficult to recover (Park *et al*., 2002; Park and Zhou, 2005). However, this can be detrimental to firm growth (Stuart, 2000). Thus, the level of competitive intensity that a firm faces is a condition to which collaboration can be utilized for best growth, and the gap between the growth from collaboration for firms facing higher and lower levels of competitive intensity is larger in more technology intensive industries.

Interestingly, the results also show that in medium-low technology intensive industries, firms facing lower levels of competitive intensity actually have less growth from collaboration as compared to firms facing higher levels of competitive intensity. One explanation is that though the more stable environment limits collaborative opportunities for firms facing higher levels of competitive intensity, these firms are likely to put more efforts into the joint activities if collaboration happens, as their survival may depend on such rare opportunities. In contrast, firms facing lower levels of competitive intensity have less incentive to collaborate and are spoilt for choice in opportunities. Thus, they may have more diluted efforts toward their collaborations upon which their survivals are not dependent. Hence, growth outcomes from collaboration may not be as great as those of firms facing higher levels of competitive intensity.

These findings provide an explanation as to why studies investigating the benefits of collaboration have provided mixed results (Stuart, 2000). Much of the discussion in the collaboration literature has assumed that collaboration is beneficial, and firms engage in collaboration whenever they desire. However, as the arguments above suggest, this observation does not take into account the difference in collaborative opportunities that are available to firms. In this case, firms facing lower

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levels of competitive intensity have a wider selection of collaborative opportunities and will engage in those that provide the best growth prospects—a process of self-selection. On the other hand, those facing higher levels of competitive intensity, due to their inferior competitive positions, are likely to have a pool of less attractive collaborative opportunities to select from. The starting point of these groups of firms differs. Thus, it is not surprising that the findings here suggest that collaboration effects on growth are dependent on firm competitive intensity and industry technology intensity.

These last findings have strong implications for collaboration in different technological environments. The proliferation of collaboration in more technology intensive industries has been due to the benefits it offers to offset competitive pressures and lower market and technological risks. Yet, warnings of the risks of losing proprietary technology and of creating future competitors have often discouraged collaboration in such industries. The finding here suggests that firms facing lower levels of competitive intensity in these industries have more to gain from collaboration than those in similar positions in less technology intensive industries. The environments of these industries are turbulent and dynamic, increasing the challenges for independent firms. Collaboration not only allows a firm to withstand competition, it also helps a firm to impose stronger competition on others (Silverman and Baum, 2002). The finding that firms facing higher levels of competitive intensity generate greater growth from collaboration than firms facing lower levels of competitive intensity in less technology intensive industries suggests the usefulness of collaboration in a more stable environment for competitively weaker firms. It also highlights the importance of accurate evaluation of growth potentials of equally attractive collaborative opportunities and follow-through implementation of collaborations to ensure that these potentials are realized. These issues certainly warrant further research. Taken together, these results also suggest that collaboration can serve the dual purposes of responding to intensified competition and being a more proactive means to impose stronger pressures on competitors. The results also show that competitive and collaborative dynamics differ across industries with different technology intensities, and both are deterministic of firm growth to varying degrees in different technological environments.

Limitations and suggestions for future research

Using the competitive dynamics perspective and the resource-based view, this study integrates four key concepts in strategy: competitive intensity, collaboration, technology intensity and firm growth, representing an initial empirical effort to explain the complex relationships between these concepts. The relationships between these concepts are likely to be intertwined, making any analysis of these relationships a difficult conceptual and empirical challenge. For example, competitive intensity and collaboration are likely to have reciprocal relationships. Future research should look at other conceptual frameworks that connect these concepts in order to further our understanding of their complex and intertwined relationships.

While this study adopted the opportunity-based approach in theorizing, I do not quantify the desires and opportunities to collaborate. Empirically measuring the supply side of collaboration, that is, collaborative opportunities available to a firm, will represent a huge challenge. Essentially, this requires firms to look beyond their existing scope and identify potential new opportunities and partners. Crucially for collaboration researchers, collaborative strategies have a unique demand-supply component that determines their incidence. Thus, more opportunity-based arguments and measurements should be included in future collaboration studies. In addition, opportunity-based arguments suggest that some firms may actually form better quality collaborations than others. This is implicit in Hypotheses 3 and 4. The current dataset however does not contain information about the quality of collaborations. Future research should quantify 'quality' collaborations established and potentially incorporate it as a component of opportunities to collaborate to further our understanding of the self-selection nature of collaboration.

To conceptualize and operationalize competition at the firm level represents another key area for development. Such attempts will help further integrate the resource-based view with the traditional industrial organization literature on competition. This study has used a firm's participating product market competition as the competitive intensity measure to test the hypotheses. The measurement has assumed that firms competing in multiple product markets place equal weighting on these product markets; 92 percent of sample firms in this study are not listed and thus data on the percentage of

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firm sales in each participating product market is not available. While this is not a strong assumption as a firm competes to survive in each of its product markets, the literature on competitor analysis (e.g., Chen, 1996) suggests the potential for more refined firm-level competition measures. Thus, future studies should seek to empirically investigate the effects of firm-level competition with alternative measures of competitive intensity. More attention in this inquiry is warranted.

Finally, this study uses industry technology intensity as a moderator. However, technology usage by individual firms within the same industry can vary (Bettis and Hitt, 1995). Thus, there is potential to test the hypotheses using a firm-level measure of technology intensity. Future studies can look into testing moderating effects of firm-level technology constructs on competitive intensity-collaboration-growth relationships.

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