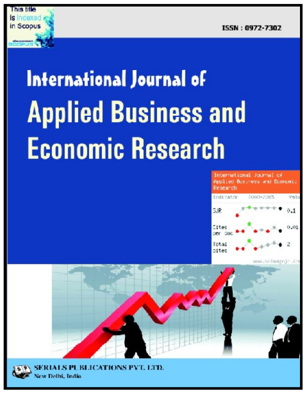

International Journal of Applied Business and Economic Research

ISSN : 0972-7302

available at http: www.serialsjournals.com

Volume 15 • Number 24 • 2017

Industry Competition and Exploration of Technological Diversity: The Moderating Effects of Firm Heterogeneities

Kwangwook Gang[1], Byungchul Choi[2*] and Seungbeom Kim[3]

[1] *Salisbury university, MD, USA*
[2] *Hankuk University of Foreign Studies, Seoul, Korea*
[3] *Hongik University, Seoul, Korea*
[*] *Correspondence: bchoi@hufs.ac.kr*

Abstract: Industry competition is one of the critical determinants of innovation strategy of the firm. Since the seminal contribution of Schumpeter, a large body of literature investigated the impacts of industry competition on innovationstrategy by mainly focusing on R&D investment.This paper adds to the extant literature on how industry competition influences a firm's explorative research in the presence of firm heterogeneities.Our findings suggest that low industry competition increases a firm's technological diversity, and this relationship is enhanced by a firm's knowledge assets, age, and financial performance, while it is weakened by firm leverage. The results of this study contribute to the extant literature. The investigation of R&D expenditure in prior literature may provide limited information regarding the impact of industry competition on a firm's innovation strategy. We extend the current literature by suggesting that a firm's explorative behavior in terms of technological diversity is the function of industry competition and firm heterogeneities.

Keywords: Industry competition; firm heterogeneities; exploration of technological diversity

I. INTRODUCTION

Industry competition has received steady attention from researchers as one of the major determinants of strategic direction of the firm [1]. In the innovation literature, the ways in which industry competition impacts a firm's innovation-related behaviors has been one of the primary interests of researchers. In particular, since the seminal contribution of Schumpeter [2], a large body of literature has investigated the impact of industry competition on investment decisions in innovation. The key research topic of previous studies involves testing the view of the Schumpeterian school that low industry competition encourages a

"Byungchul Choi's work was supported by 2017 Hankuk University of Foreign Studies Research Fund"
"Senungbeom Kim's work was supported by 2015 Hongik University Research Fund"

firm to engage in more technological progress because low competition allows firms to spend relatively more resources on innovation [3].

However, most of the prior literature has focused on the change of R&D expenditure, rather than a firm's actual behavior to explore new knowledge [4], and has shown inconsistent findings. One of the most plausible explanations for these inconsistent results is an "oversimplified assumption of innovation [3, 5]". Simply using aggregate R&D expenditures as proxy for innovation behavior may minimize the consideration of the technological nature of innovation such as the innovation type or quality [3], previous studies may not fully capture the detailed picture of the association between industry competition and actual innovation activities directly related to technological progress. Also, the importance of firm's heterogeneous characteristics for innovation in the presence of industry effects has received only limited attention and empirical support from existing literature [4].

In the present study, we aim to investigate how industry competition and its interaction with a firm's heterogeneous characteristics impact the firm's exploration of technological diversity. To capture a firm's exploration of technological diversity, we used international patent classifications (IPCs) class overlap to estimate the novelty of the knowledge. Technological diversity can provide meaningful implications as it reflects a trajectory and background of a firm's technology strategy [6, 7]. We tested hypotheses using the patent and the financial data from 94 Korean manufacturing firms from 1998 to 2008 and found that industry competition decreases the degree of explorative research of the firm. This finding supports the Schumpeterian hypothesis that more explorative inventions will be generated when firms are in an industry with less competition. Furthermore, we also found that in the presence of low industry competition, the exploration of new technologies will be strengthened when firms have greater knowledge assets, experience, and performance, while it will be weakened when firms have more debt.

Our research contributes to the strategy and innovation literature. Prior literature has primarily focused on the impacts of industry competition on R&D expenditures at the firm level. This focus may deliver limited implications to managers, who must consider the balance between exploration and exploitation with limited resources under competition. We comprehensively tested the impacts of industry competition on technological exploration by using the concept of the exploration of technological diversity [8]. Our findings fill the gap in the extant literature by providing various contingencies upon which firms explore more diverse and new knowledge under the dynamics of industry competition.

II. THEORETICALBACKGROUND

Industry competition and innovation strategy of the firm

Since the seminal work of Schumpeter [2], a large body of literature has focused on the association between industrial competition and a firm's innovation strategy. The Schumpeterian school views, to firms, low industry competition as an ideal setting to achieve more technological progress because it reduces market uncertainty so that firms can secure more resources to engage in costly and risky R&D projects [2]. This positive aspect of monopolistic market for innovation has been supported by prior studies [9, 10, 11, 12, 13]. For example, based on the equilibrium model Loury[14] found that harsh competition deteriorates a firm's motivation to invest R&D. Geroski[11] investigated UK industries in the 1970s and provided evidence showing that price wars in a competitive market decrease a firm's innovativeness.

However, despite of its great influence, the validity of the Schumpeterian hypothesis remainsinconclusive[4], and other researchers have exhibited controversial results. Aghion et al [15] found the existence of a non-linear relationship between industry competition and innovation. Also Levin et al [16] and Scott [17] showed that industry competition provides a fairly limited explanatory power to understand for the variance in R&D expenditures. One of the most plausible explanations for these inconsistent results is an "oversimplified assumption of innovation" [3, 5]. By simply using aggregate R&D expenditures and minimizing consideration of the nature of innovation such as the innovation type [3], previous studies may not fully capture the picture for the association between industry competition and innovation.

Exploration of technological diversity as an innovation strategy

After introduced the concepts of exploration and exploitation, balancing these two activities (also known as ambidexterity) became one of the primary frameworks used to analyze the innovation strategy of a firm [18, 19]. In previous studies, technological diversity has been viewed as one of the estimators to predict the tendency toward exploring new knowledge of the firm [20]. Exploration allows firms to discover new technological capabilities for future business, while exploitation enhances the efficiencies of existing technological capabilities within a firm [21, 22, 23].

Researchers claim that in general firms have a tendency to manage a wider range of technological diversity than they actually need for their current product portfolios [24, 25, 26] since technological diversity increases a firm's strategic scope of opportunities [27, 28]. Firms can benefit from technological diversity in multiple manners. First, diversified technological capabilities increase firms' ability to capture potential opportunities for new business in highly turbulent markets [29, 30, 31]. Silverman [32] found that firms are more willing to diversify into industries in which they can utilize existing and applicable technological resources. Also by utilizing this growth opportunity based on technological capabilities, firms can increase their value [27] and attain higher profitability [33]. Second, from the standpoint of investment, technological diversity can reduce the risk of technology portfolios [34]. Hence a diversified technological portfolio is becoming a prevailing phenomenon in industrialized regions and in high technology sectors [26].

Firm heterogeneity and technological diversity

While industry competition matters for shaping the innovation strategy of a firm, firm-specific homogeneous characteristics can be considered as key determinants for innovation strategy [35]. As an independent economic entity, a firm can differently adapt to the environment [36], and build competitive advantages based on the interactions between firm-specific strategic orientation and industry characteristics [37]. In this context, technological diversity is the consequence of interactions between a firm's heterogeneous features and industrial characteristics. Hence, a voluminous body of work has investigated various firm-specific characteristics as a factor to influence technological diversity including - knowledge relatedness [38], technology roadmaps [39], internationalization [40], size [25], core business [25], technological platforms [31], diversification strategies [20], product diversification [39], alliances [42], and technological resources [32] and so on. In the present study, we focused on the moderating effects of four firm-specific characteristics - knowledge assets, leverage, firm age, and firm performance - and investigated how these four factors interact with industry competition to determine the technological diversity of a firm.

III. HYPOTHESISDEVELOPMENT

3.1. Industry competition and innovation strategy of the firm

In low competition industries dominated by a small number of large firms, those established firms are more willing to take on risky and innovative projects based on an abundance of resources [2]. While the argument in respect to the large firms' motivation to conduct innovative research has been well-documented in previous literature, the motivation for innovative research in small firms has received relatively less attention.

For the small or medium firms sized firms, finding a niche is one of the attractive and explorative innovation strategies. Based on the early work of Hannan and Freeman [43], a niche can be defined as economic conditions in a marketplace supporting a specific type of business or firm. Since small firms often encounter various hardships to directly compete with established firms in terms of product quality or process efficiency, they have a tendency to create value that is economically meaningful but different from that of those large firms [44]. Empirical studies show that the number of realized economic niches is inversely proportional to the degree of market competition, thereby implying that monopolistic markets motivate small firms to find a explore undiscovered niches [45, 46]. Similarly, Bakker et al. [47] argued that niches can lead firms to achieve radical innovations by stimulating the flow of new ideas. Hence we assume that regardless of its position (either large or small firms) within an industry, firms are likely to have motivation to conduct more explorative research when industry competitionis low (increase inmonopoly within themarket).[1]Therefore, we hypothesize the following.

Hypothesis 1: Lower competition will have a positive relationship with the degree of exploration of technological diversity (Hence, the higher industrial competition will be negatively related to the degree of exploration of technological diversity)

3.2. Knowledge assets

Technological knowledge is one of the unique firm-specific assets [48], and previous research provides theoretical and empirical support for the positive association between knowledge assets and innovative tendency of the firm. The accumulation of knowledge enhances the firms' ability and increase the chance to engage in further explorative research [38, 49]. Knowledge-based resources increase the probability of success for the firms' entrepreneurial activities [50]. We assume that established knowledge assets such as patents stock can provide a firm with more opportunities for innovative research because, in the presence of industry competition, firms will try to maximize the value of their existing knowledge to find new business opportunities. Therefore, we postulate the following hypothesis.

Hypothesis 2: Knowledge assets will strengthen the positive relationshipbetween low industrial competition (predicted in Hypothesis 1) and the degree of exploration of technological diversity.

3.3. Firm leverage

Debt can be defined as contract-based market governance that promises mandatory payment from future cash flows to debt holders [51]. Although debt is one of the key sources of financing [52], the risks and uncertainty naturally embedded in innovation such as the uncertainty of outcomes [53], intangibility [54], and low collateral value [55] make debt a less attractive option for R&D-intensive firms. All of the risks rooted in innovation preclude debt from being a favored as financing source for risky projects [56], and equity is preferred over debt for risky or innovative projects [57]. Particularly, in the presence of industry competition which may confine the available strategic choices of a firm, we assume that high leverage will restrict firms from exploring new unknown knowledge that contains risk and uncertainty. Hence, we propose the following hypothesis.

Hypothesis 3. Leverage will weaken the positive relationship between low industrial competition (predicted in Hypothesis 1) and the degree of exploration of technological diversity.

3.4. Firm age

In general mature firms have inertia to follow previously established routines and skills [58], and it may deteriorate or restrict the firm's motivation to pursue new innovative strategies [59]. However, scholars argue that older firms may generate more important innovations [60] based on their resources, established routines and experiences which enable firms to avoid unnecessary actions [49, 58, 61]. While organizational inertia is a general concept that can be applied to any type of organization, we assume that a technology-based firm (which is main interest group in our study) is an organization that intentionally and constantly aims to maximize the innovativeness of their technologies. Given this assumption, older firms have a stronger incentive to conduct a wide range of research in the presence of industry competition because they can more efficientlyestablish routines and experience tointerpret and extract the value of explorative knowledge. Thus, we hypothesize the following.

Hypothesis 4: Firm age will strengthen the positive relationship between low industrial competition (predicted in Hypothesis 1) and thedegree ofexploration of technological diversity.

3.5. Firm performance

The importance of financial flexibility for innovation has constantly been highlighted by researchers [62]. R&D-intensive firms generally try to reserve extra internal cash to capture future innovation opportunities [63] since poor firm performance (e.g. low profits or limited market share) restricts firms from exploring new knowledge [41]. Empirical evidence shows that firms with restricted financial flexibility produce less and lower quality innovation[64]. To summarize, firms need an appropriate level of economic returns for to push new innovative projects ahead. Therefore, we propose the following hypothesis.

Hypothesis 5. Firm performance will strengthen the positive relationship betweenlow industrial competition (predicted in Hypothesis 1) and the degree of explorationof technological diversity.

Our conceptual model and hypotheses are summarized in Figure 1.

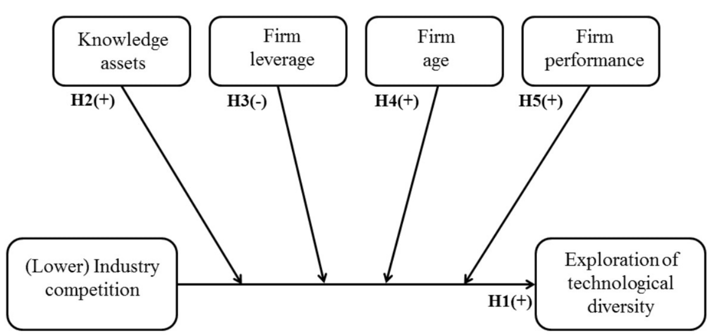

Figure 1: Conceptualframeworkand hypothesis

4. METHODS

4.1. Data and sample

The focus of the present study is to capture the variability in the behavior of a firm within the context of exploitation and exploration in term of technological diversity. We constructed our sample using patent data from Korean manufacturing firms from 1998 to 2008. Korea is one of the countries managing the successful transformation of its economy [65] through constant efforts to develop technological capabilities [66]. Because Korean companies have transformed themselves from imitators who focus on operational efficiency with existing knowledge to innovators that must approach the innovation frontier [67] in terms of technological capabilities [68], we assume that the patent activities of Korean firms can provide appropriate data with which to investigate the behavior of R&D-intensive firms searching for an optimal position between exploitation and exploration. Also after a series of market reforms by the Korean government in 1997, most of the Korean firms encountered increased industrial competition that required them to increase explorative research [69]. To test our hypotheses, we collected financial information and the patent record for each firm. First, we obtained patent information from the Korea Intellectual Property Rights Information Service (KIPRIS) database owned and managed by the Korea Institute of Patent Information (KIPI). The initial sample consisted of 689 Korean manufacturing firms in 26 industries classified by four digits of the Korean Standard Industrial Classification (KSIC): Energy, Materials, Capital Goods, Automobiles and Components, Health Care, Health Care Equipment and Services, Pharmaceuticals and Biotechnology, Software and Services, Technology Hardware and Equipment, Semiconductors and Semiconductor Equipment, and Telecommunication Services. Next, to extract company profiles and financial information, we used the Korea Investors Services Value (KIS) database, which has been used in previous studies [66, 70]. By combining these two databases, we ultimately identified 94 firms listed in the Korean Stock Exchange (KSE) market. From this dataset, we measured the technological distance of the firms and the industry competition in each year.

4.2. Variables and measures

Dependent variable

In our study, we used the concept of the exploration of technological diversity to estimate a firm's tendency to explore new technological areas. A high value of technological diversity compared to prior years implies more explorative research conducted by a firm. Based on previous studies, the degree of exploration on technological diversity is measured by technological distance among patents. To construct technological distance, we used IPCs (International Patent Classifications) from the WIPO (World Intellectual Property Organization). The usage of IPC codes to analyze technological capability has been established in the prior literature [71, 72]. We considered patent classes as a technological class to locate the each patent after registration[2]. Once the p vector was set to describe each patent's location in a dimension (IPC), we used Euclidean distance (E) to compare two vectors representing the set of patent classes listed for each firm's patents [73, 74]. Based on the concepts of technological distance and Euclidean distance (E), Exploration of technological diversity is defined in our study as follows:

$$\textit{Exploration of technological diversity} = \sqrt{\sum_{c=1}^{N}\left(P_{i,t+1}^{c} - P_{i,t}^{c}\right)^2}$$

where Pcis the ratio of the number of patents belonging to patent class c in yeart + 1 within firm i to the total number of patents in year t + 1 within the same firm i. Pcwas calculated in the same way as Pcby using year t. N is the number of dimensions (patent classes) defined by International Patent Classifications (IPCs). Therefore, if a firm registered no patents or did not develop any patents that should belong to a new patent class in year t, the technological distance of this firm is zero.We used a logarithm of this measure.

Independent variables

Industry competition is measured by the Herfindahl-Hirschman Index (HHI) in four digit KSIC industry level. HHI has been conventionally used to measure industry competition across the fields of business [75]. The HHI is calculated as follows:

$$HHI = \sum_{i=1}^{N} R_i^2$$

where *Ri* denotes the proportion of firm i's sales over total four-digit KSIC industry sales. A small value for the HHI indicates a competitive industry (more firms in the same industry), while a large value means less competition (less firms in the same industry, hence more monopolistic). Therefore, a more monopolistic market (lower industry competition) will have a higher value for the HHI. The U.S. Department of Justice considers a market with an HHI value from 0.1 to 0.18 to be a moderately concentrated marketplace and a market with an HHI value over 0.18 to be a highly concentrated marketplace [76]. Because a high value for the HHI represents high monopolism(low competition), a high value for the HHI refers to low industry competition [77]. Therefore, if HHI is positively related to the degree of exploration of technological diversity, this means lower competition will be positively related to the degree of exploration of technological diversity (noted in H1). We used a logarithm of the total number of patents registered in the previous year to control for a firm's knowledge assets because the number of patents that a firm owns can deteriorate the firm's motivation to explore new innovation[78]. Firm leverage was measured using debt equity [79]. We measured firm age as the year gap between the foundation year and the year in which a firm was observed in our sample [66]. We adopted Return on Assets (ROA) as the measure of firm performance [66].

Control variables

We used several control variables at the firm level and industry level. We measured R&D intensity as the ratio of R&D expenditures to total sales [79]. We controlled for technological distance, the dependent variable, with a one-year lag to observe the carryover effect.Financial slack was measured as the fraction of the sum of cash and marketable securities over total liabilities [80]. To control for firm size, we used a logarithm of total sales [66]. We also generated a group dummy and gave the value one if a firm belonged to one of the top 30 business groups in Korea as defined by the Korea Fair Trade Commission, which identifies business groups annually by the size of total assets [66]. Lastly, because we used a fixed-effect regression model with panel data, the industry code (KSIC) was an invariant factor in the within-firm data. To include industry effects into the test result we used technological distance averaged by four-digit KSIC codes.

4.3. Empirical methodology

We constructedlongitudinal data and employed fixed effects regression to control unobserved heterogeneity among sample firms. The goal of this study is to investigate the relationship between industry competition and technological distance. To control unobserved, a fixed effects regression is employed, similar to prior studies [81]. Furthermore, the result of a Hausman test also suggests using the fixed effects rather than random effects regressions. All independent variables and controls were lagged by one year. The one-year lagging of all independent variables and controls has some benefits: 1) technological distance is determined based on prior contingencies and 2) the one-year lagging mitigates potential endogeneity. All interaction variables were mean-centered to avoid multicollinearity [82].

The base model is expressed in the following general form:

$$TDi,t = b0 + b1 \times ICj,t–1 + b2–n \times Controlsi,\ t–1 + e \quad \text{(Model1)}$$

TD i,t in Model 1 is the technological distance of firm i between time t and time t + 1, and ICj, t–1 indicates the level of competition in industry j at time t – 1. b0 represents a constant, b1 represents industry competition, and b2–n are controls of the estimated coefficients. e is an error term. Model 2 also includes four firm heterogeneities in the base relationship: the number of patents, firm leverage, firm age, and firm performance.

$$\begin{aligned} TDi,t = {} & b0 + b1 \times ICj,t–1 + b2 \times PAi,t–1 \times ICj,t–1 \\ & + b3 \times FLi,t–1 \times ICj,t–1 + b4 \times FAi,t–1 \times ICj,t–1 \\ & + bs \times FPi,t–1 \times ICj,t–1 + b6–n \times Controlst,\ t–1 + e \end{aligned} \quad (Model2)$$

P A i, t–1 is the number of patents of firm i at time t – 1, F Li,t–1 is the firm leverage of firm i at time t – 1, F Ai,t–1 is the firm age of firm i at time t – 1, and F Pi,t–1 shows the performance of firm i at time

Table 1
Correlations and Descriptive statistics

	Variable	*Mean*	*s.d*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
1.	Exploration of Tech diversity[a]	-0.73	0.75											
2.	(Prior) Exploration of Tech diversity[a]	-0.70	0.75	0.71*										
3.	HHI (Industry Competition)	0.19	0.22	-0.24*	-0.27*									
4.	R&D Intensity	0.03	0.04	-0.26*	-0.28*	0.28*								
5.	Knowledge assets[a]	2.31	1.89	-0.77*	-0.80*	0.34*	0.32*							
6.	Firm leverage	1.05	1.44	0.01*	0.01*	-0.05*	-0.04*	-0.01*						
7.	Firm age	33.25	15.54	0.03*	0.02*	-0.26*	-0.12*	-0.05*	-0.01*					
8.	Firm performance	4.42	8.07	0.05*	-0.02*	-0.03*	-0.20*	-0.01*	-0.07*	-0.04*				
9.	Financial slack	0.22	0.34	0.03*	0.04*	0.07*	0.22*	0.01*	-0.22*	-0.13*	0.12*			
10.	Firm size[a]	12.57	1.57	-0.45*	-0.50*	0.05*	-0.10*	0.62*	0.01*	0.15*	0.10*	-0.19*		
11.	Group dummy	0.31	0.46	-0.28*	-0.30*	-0.05*	-0.03*	0.42*	0.15*	-0.10*	-0.04*	-0.22*	0.65*	
12.	Industry Tech. distance	-0.63	0.34	0.41*	0.48*	-0.64*	-0.34*	-0.50*	0.04*	0.18*	0.06*	-0.16*	-0.21*	-0.04

N = 639 (Firms: 94, during 1998-2008, unbalanced panel data)
a natural logarithm
* $p< 0.05$

$t - 1$. bk 's are the estimated coefficients (k = 0,1,..., 5, 6 – n). The other variables are same as in Model 1. Hypothesis 1 expects that firms explore new knowledge when they are in a monopolistic industry, suggesting a positive and significant coefficient of b1 in both Model 1 and Model 2. Positive and significant coefficients of b2, b4, and b5 and a negative and significant coefficient of b3 are expected to support Hypotheses 2-5 in Model 2.

5. RESULTS

From the initial data set, 639 observations from 94 firms were analyzed. Table 1 shows the means, standard deviations, and correlations between all variables. Table 2 shows the results of the fixed-effect regressions. Model 1 includes only control variables. Model 2 shows the main effect between industry competition and technological distance. Models 3-7 show the moderations of R&D input and output and firm heterogeneities including leverage, age, and performance.

In Hypothesis 1, we proposed that lower industry (=high HHI) competition will be positively related to the degree of exploration of technological diversity, meaning HHI should be positively associated with the degree of exploration of technological diversity). The positive coefficient ($\beta = 2.244$, $p < .01$) of the HHI in Model 2 provides a support for Hypothesis 1. In Hypothesis 2, we predicted that a firm's knowledge assets strengthen the relationship between the HHI and the exploration of technological diversity. Model 3 shows a positive and marginally significant result ($\beta = 0.185$, $p < .1$). This result supports Hypothesis 2 and is consistent with the results from previous studies [38, 50]. Such result implies that firms with more patents explore new knowledge when they are in industries with low competition. Interestingly, the direct relationship has a negative and significant coefficient, which can mean that the number of patents held by a firm enhances the firm's exploitation of existing knowledge rather than its exploration of new knowledge. However, industry competition changes a firm's technological behavior. In support of Hypothesis 3, the negative and significant coefficient of the interaction term ($\beta =$ Š0.391, $p < .01$) in Model 4 indicates that high leverage leads firms to pursue less exploration, while less industry competition increases technological exploration. In Hypothesis 4, we posited that older firms explore new knowledge more than smaller firms because older firms have more experience and capabilities. The result of Model 5 shows a positive and significant coefficient ($\beta = 0.059$, $p < .05$). The model supports Hypothesis 4, indicating that older firms will pursue new knowledge when industry competition is low based on their accumulated knowledge and established routines [58, 60, 61]. The positive interaction term in Model 6 ($\beta = 0.032$, $p < .01$) implies that financial flexibility enhances the relationship between low industry competition and the exploration of technological diversity. All moderating effects of are summarized in Figure 2.

Among the control variables, the group dummy linked to the number of patents registered in the previous year shows a strong negative coefficient in all models, while the group dummy illustrates a significant and positive impact on technological distance. Regarding the effects of the number of patents, one possible explanation can be that a firm that produces new knowledge may need some time to absorb and combine new knowledge with its existing knowledge.

CONCLUSIONAND DISCUSSION

Since the seminal contribution of Schumpeter [2], various studies have examined the impacts of industry competition on the innovation behaviors of firms. Although this series of work focuses on the impact of

Table 2
Results of Fixed-effect Regressions

		Exploration of tech. diversity $_{t+1}$					
Variables $_t$		*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
Constant		5.465**	5.022**	5.259**	5.303**	5.200**	5.335**
		(1.869)	(1.854)	(1.853)	(1.843)	(1.851)	(1.842)
Exploration of tech. diversity		0.013	0.012	0.016	0.019	0.018	0.028
		(0.047)	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)
Financial slack		0.089	0.081	0.078	0.057	0.086	0.075
		(0.088)	(0.087)	(0.087)	(0.087)	(0.087)	(0.086)
Firm size[a]		-0.058	-0.048	-0.064	-0.057	-0.035	-0.058
		(0.053)	(0.053)	(0.053)	(0.053)	(0.053)	(0.053)
Group dummy		0.282†	0.320*	0.302*	0.297†	0.303*	0.316*
		(0.153)	(0.152)	(0.152)	(0.151)	(0.152)	(0.151)
Industry tech.distance		0.217	0.061	0.034	0.039	-0.038	0.000
		(0.136)	(0.142)	(0.142)	(0.141)	(0.150)	(0.142)
R&D intensity		0.879	0.970	0.968	1.127	1.030	0.842
		(1.190)	(1.178)	(1.175)	(1.171)	(1.175)	(1.170)
Knowledge assets[a]		-0.270**	-0.272**	-0.308**	-0.276**	-0.272**	-0.271**
		(0.028)	(0.028)	(0.034)	(0.028)	(0.028)	(0.028)
Firm leverage		-0.008	-0.003	-0.003	0.072*	-0.001	-0.001
		(0.016)	(0.016)	(0.016)	(0.030)	(0.016)	(0.016)
Firm age		-0.124**	-0.132**	-0.129**	-0.137**	-0.142**	-0.138*
		(0.046)	(0.046)	(0.046)	(0.045)	(0.046)	(0.045)
Firm performance		0.010**	0.012**	0.012**	0.011**	0.011**	0.002
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)
HHI (Industry competition)	H1(+)		2.244**	1.841**	1.580*	1.928**	2.464**
			(0.654)	(0.685)	(0.688)	(0.672)	(0.653)
HHI×Knowledge assets	H2(+)			0.185†			
				(0.095)			
HHI Firm leverage	H3(-)				-0.391**		
					(0.134)		
HHI Firm age	H4(+)					0.0591*	
						(0.030)	
HHI Firm performance	H5(+)						0.032**
							(0.010)
R²F		0.29	0.31	0.31	0.32	0.31	0.32
		9.79***	10.05***	9.78***	10.10***	9.81***	10.15***

N = 639

a natural logarithm

Standard errors in parentheses; Year dummy is included, but not reported here.

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

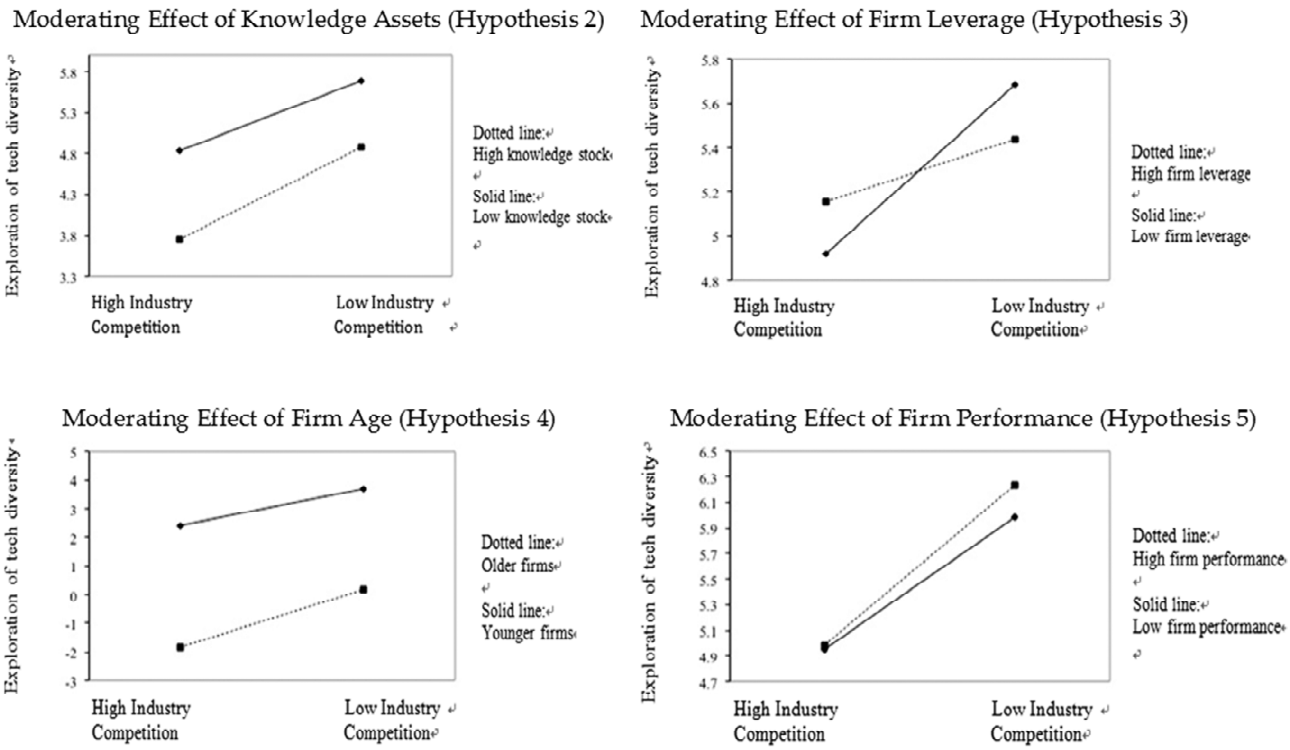

Figure 2: Summary of moderating effects of firm heterogeneities on exploration of technological diversity

industry competition on R&D investment, ambiguity surrounding how industry competition affects the direction of innovation remainsunanswered. After March [18]'s prominent study of exploration and exploitation, the direction of a firm's innovation behavior became an important research topic. The goal of this paper is to investigate the impact of industry competition on the exploration of technological diversity.

We predicted that low industry competition increases a firm's technological exploration by investing in the increase of technological diversity in patent data. From the industry evolution perspective, less industry competition is expected under the conditions of both an early phase and after the shakeout of industry evolution. The early phase of industrial development includes an "era of ferment" in which firms develop various versions of products because there is no dominant design in the market [83]. Additionally, in the phase "after a shakeout," a few firms enjoy the competitive advantages of having greater R&D capabilities compared with the competitors [84]. Greater R&D capability will enhance technological exploration when there are few competitors.

The analysis on the sample of Korean firms adds to our argument. The results revealed that lower industry competition increases a firm's exploration of technological diversity. This finding is consistent with the behavioral theory of R&D investment. Greve[80] concluded that firms will do "slack searches" when they have excess of resources. In other words, when firms have a greater slack, R&D intensity will increase. Our findings are also aligned with Greve[80]'s argument that firms in a less competitive market do not need to spend their resources to compete with other firms. Slack resources in a less competitive environment can be invested into searching for new knowledge for the future. Thus, a firm's technological diversity increases when the firm is under less competitive circumstances. Furthermore, we found that this base relationship is intensified by the firm resources and experience, such as knowledge assets, firm performance, and firm age. However, firm leverage weakens the base relationship. Resources and experience represent the degree of available slack for firms. Thus, firms with greater resources and experience are able to expand their boundaries. In terms of firm leverage, debt illustrates available resources, but it should be invested in decisions with high certainty. Because R&D investment has high levels of uncertainty and intangible characteristics [57], it is negatively related to firm leverage. Hence, firms with greater debt would lessen their degree of technological exploration to reduce uncertainty.

The results of this study contribute to the extant literature. We extend the current literature by providing results related to industry competition and a firm's explorative behavior in terms of technological diversity. The investigation of R&D investments in prior literature may provide limited information regarding the impact of industry competition on a firm's innovation strategy. Thus, we tested the impacts of industry competition on technological exploration. Consistent with Schumpeter's argument, firms pursue technologically diversified innovation when they operate within a monopolistic industry.

NOTES

1. In our analysis, we did not separate the groups by dominant and non-dominant firms. Instead, we controlled the firm size. Scrutinizing a firm's behavior in terms of innovation as a result of the level of dominancy in the industry could be a subject of future research.
2. TheInternationalPatentClassification (IPCs) comprisesthecombinedsymbolsindicatingthesection,class,subclassand main group or subgroup. We used patent classifications from the section to the subclass, which have been used in other studies [72]

REFERENCES

Ahuja, G., Lampert, C. M., & Tandon, V. 2008. Moving Beyond Schumpeter: Management Research on the Determinants of Technological Innovation. *Academy of Management Annals,* 2: 1–98.

Schumpeter, J. A. 1950. *Capitalism, Socialism, and Democracy (3rd ed.).* New York: Harper.

Joglekar, P., & Hamburg, M. 1989. Industry concentration and allocation of resources to basic research. *Management Science*, 35: 208–225.

Høyvarde Clausen, T. (2013). Firm heterogeneity within industries: how important is 'industry'toinnovation?. Technology Analysis & Strategic Management, 25: 527-542.

Marsili, O., &Verspagen, B. 2002. Technology and the dynamics of industrial structures: an empirical mapping of Dutch manufacturing. *Industrial and Corporate Change*, 11: 791–815.

Dosi, G. 1982. Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change. *Research policy*, 11: 147–162.

Sampson, R. C. 2007. R&D alliances and firm performance: the impact of technological diversity and alliance organization on innovation. *Academy of Management Journal,* 50: 364–386.

Almeida, P., &Kogut, B. 1997. The exploration of technological diversity and geographic localization in innovation: Start-up firms in the semiconductor industry. *Small Business Economics,* 9: 21–31.

Arrow, K. 1962. Economic welfare and the allocation of resources for invention. In R. Nelson (Ed.), *The rate and direction of inventive activity: Economic and social factors*:609-626. Princeton, NJ: Princeton University Press.

Blundell, R., Griffith, R., G Van Reenen, J. 1999. Market share, market value and innovation in a panel of British manufacturing firms. *The Review of Economic Studies,* 66: 529–554.

Geroski, P. A. 1990. Innovation, technological opportunity, and market structure. *Oxford Economic Papers,* 42: 586–602.

Nickell, S. J. 1996. Competition and corporate performance. *Journal of political Economy,*104: 724–746.

Scherer, F. M. 1980. *Industrial Market Structure and Economic Performance.* Boston, MA: Houghton-Mifflin

Loury, G. C. 1979. Market structure and innovation. *The Quarterly Journal of Economics,* 93:395–410.

Aghion, P., Bloom, N., Blundell, R., Griffith, R., & Howitt., P. 2005. Competition and innovation: An inverted-U relationship. *The Quarterly Journal of Economics,* 120: 701–728.

Levin, R. C., Cohen, W. M., & Mowery, D. C. 1985. R&D appropriability, opportunity, and market structure: new evidence on some Schumpeterian hypotheses. *The American Economic Review*, 75: 20–24.

Scott (1984).

March, J. G. 1991. Exploration and exploitation in organizational learning. *Organization Science,* 2: 71–87.

Tushman, M. L., & O'Reilly III, C. A. 1996. Ambidextrous organizations: managing evolutionary and revolutionary change. California management review, 383-30.

Miller, D. J. 2004. Firms' technological resources and the performance effects of diversification: a longitudinal study. *Strategic Management Journal*, 25: 1097–1119.

Benner, M. J., &Tushman, M. L. 2003. Exploitation, exploration, and process management: The productivity dilemma revisited. *Academy of Management Review,* 28: 238–256.

Katila, R., & Ahuja, G. 2002. Something old, something new: A longitudinal study of search behavior and new product introduction. *Academy of Management Journal*, 45 : 1183–1194.

Uotila, J., Maula, M., Keil, T., & Zahra, S. A. 2009. Exploration, exploitation, and financial performance: analysis of S&P 500 corporations. S*trategic Management Journal*, 30: 221–231.

Patel, P., & Pavitt, K. 1997. The technological competencies of the world's largest firms: complex and path-dependent, but not much variety. *Research policy,* 26: 141–156.

Pavitt, K., Robson, M., & Townsend, J. 1989. Technological accumulation, diversification and organisation in UK companies, 1945–1983. *Management Science*, 35: 81–99.

Leten, B., Belderbos, R., & Van Looy, B. 2007. Technological diversification, coherence, and performance of firms. *Journal of Product Innovation Management*, 24: 567–579.

Miller, D. J. 2006. Technological diversity, related diversification, and firm performance. *Strategic Management Journal,* 27: 601–619.

Argyres, N. 1996. Capabilities, technological diversification and divisionalization. *Strategic Management Journal,* 17: 395–410.

Pavitt, K. 1998. Technologies, products and organization in the innovating firm: what Adam Smith tells us and Joseph Schumpeter doesn't. *Industrial and Corporate Change*, 7: 433–452.

Lin, B. W. (2011). Knowledge diversity as a moderator: inter-firm relationships, R&D investment and absorptive capacity. *Technology Analysis & Strategic Management,* 23(3), 331-343.

Kim, D.-J., &Kogut, B. 1996. Technological platforms and diversification. *Organization Science,* 7: 283–301.

Silverman, B. S. 1999. Technological resources and the direction of corporate diversification: Toward an integration of the resource-based view and transaction cost economics. *Management Science*, 45: 1109–1124.

Gemba, K., & Kodama, F. 2001. Diversification dynamics of the Japanese industry. *Research Policy,* 30: 1165–1184.

Garcia-Vega, M. 2006. Does technological diversification promote innovation?: An empirical analysis for European firms. *Research Policy*, 35: 230–246.

Hadjimanolis, A. 2000. A resource-based view of innovativeness in small firms. *Technology Analysis & Strategic Management,* 12: 263-281.

Spanos, Y. E., Zaralis, G., &Lioukas, S. 2004. Strategy and industry effects on profitability: evidence from Greece. *Strategic Management Journal,* 25: 139–165.

Porter, M. E. 1991. Towards a dynamic theory of strategy. *Strategic Management Journal* 12: 95–117.

Breschi, S., Lissoni, F., &Malerba, F. 2003. Knowledge-relatedness in firm technological diversification. *Research Policy,* 32: 69–87.

Piscitello, L. 2000. Relatedness and coherence in technological and product diversification of the world's largest firms. *Structural Change and Economic Dynamics*, 11: 295–315.

Granstrand, O. 1998. Towards a theory of the technology-based firm. *Research policy*, 27: 465–489.

Miller, D. J. 2004. Firms' technological resources and the performance effects of diversification: a longitudinal study. *Strategic Management Journal*, 25: 1097–1119.

Lavie, D., &Rosenkopf, L. 2006. Balancing exploration and exploitation in alliance formation. *Academy of Management Journal,* 49: 797–818.

Hannan, M. T., & Freeman, J. 1977. The population ecology of organizations. *American Journal of Sociology,* 82:929–964.

Echols, A., & Tsai, W. 2005. Niche and performance: the moderating role of network embeddedness. *Strategic Management Journal*, 26: 219–238.

Sorenson, O., McEvily, S., Ren, C. R., & Roy, R. 2006. Niche width revisited: organizational scope, behavior and performance. *Strategic Management Journal*, 27: 915–936.

Tisdell, C., &Seidl, I. 2004. Niches and economic competition: implications for economic efficiency, growth and diversity. *Structural Change and Economic Dynamics,* 15: 119–135.

Bakker, S., van Lente, H., & Engels, R. 2012. Competition in a technological niche: the cars of the future. *Technology Analysis & Strategic Management*, 24: 421–434.

Garcia, R., Calantone, R., & Levine, R. 2003. The role of knowledge in resource allocation to exploration versus exploitation in technologically oriented organizations. *Decision Sciences*, 34: 323–349.

Cohen, W. M., &Levinthal, D. A. 1990. Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly,* 35:128–152.

Wiklund, J., & Shepherd, D. 2003. Knowledge-based resources, entrepreneurial orientation, and the performance of small and medium-sized businesses. S*trategic Management Journal*, 24: 1307–1314.

Williamson, O. E. 1988. Corporate finance and corporate governance. *The Journal of Finance,* 43: 567–591.

David, P., O'Brien, J. P., & Yoshikawa, T. 2008. The implications of debt heterogeneity for R&D investment and firm performance. *Academy of Management Journal*, 51: 165–181.

Laverty, K. J. 1996. Economic "short-termism": The debate, the unresolved issues, and the implications for management practice and research. *Academy of Management Review,* 21: 825–860.

Simerly, R. L., & Li, M. 2000. Environmental dynamism, capital structure and performance: a theoretical integration and an empirical test. *Strategic Management Journal,* 21: 31–49.

Hall, B. H. 2002. The financing of research and development. *Oxford Review of Economic Policy,* 18: 35–51.

Hall, B. H. 1992. *Investment and research and development at the firm level: does the source of financing matter?* Working paper no.4096, National Bureau of Economic Research.

O'Brien, J. P. 2003. The capital structure implications of pursuing a strategy of innovation. *Strategic Management Journal*, 24: 415–431.

Hannan, M. T., & Freeman, J. 1984. Structural inertia and organizational change. *American Sociological Review,* 49:149–164.

Kelly, D., &Amburgey, T. L. 1991. Organizational inertia and momentum: A dynamic model of strategic change. *Academy of Management Journal,* 34: 591–612.

Sørensen, J. B., and T. E. Stuart. 2000. Aging, obsolescence, and organizational innovation. *Administrative Science Quarterly,* 45: 81–112.

Tushman, M. L., & Anderson, P. 1986. Technological discontinuities and organizational environments. *Administrative Science Quarterly,* 31:439–465.

Rothaermel, F. T. 2001. Incumbent's advantage through exploiting complementary assets via interfirm cooperation. *Strategic Management Journal,* 22: 687–699.

Bates, T. W., Kahle, K. M., &Stulz, R. M. 2009. Why do US firms hold so much more cash than they used to? *The Journal of Finance*, 64: 1985–2021.

Atanassov, J., Nanda, V., &Seru, A. 2007. Finance and innovation: the case of publicly traded firms. Unpublished working paper, University of Michigan.

Mahmood, I. P., &Rufin, C. 2005. Government's dilemma: The role of government in imitation and innovation. *Academy of Management Review,* 30: 338–360.

Kim, H.,Kim, H., & Lee, P. M. 2008. Ownership structure and the relationship between financial slack and R&D investments: Evidence from Korean firms. *Organization Science*, 19: 404–418.

Lee, K., & Lim, C. 2001. Technological regimes, catching-up and leapfrogging: findings from the Korean industries. *Research Policy,* 30: 459–483.

Hobday, M., Rush, H., & Bessant, J. 2004. Approaching the innovation frontier in Korea: the transition phase to leadership. *Research Policy*, 33: 1433–1457.

Chari, M. D., & David, P. 2012. Sustaining superior performance in an emerging economy: an empirical test in the Indian context. *Strategic Management Journal*, 33: 217–229.

Chang, S. J. 2003. Ownership structure, expropriation, and performance of group-affiliated companies in Korea. *Academy of Management Journal*, 46: 238–253.

Benner, M., &Waldfogel, J. 2008. Close to you? Bias and precision in patent-based measures of technological proximity. *Research Policy*, 37: 1556–1567.

Suzuki, J., & Kodama, F. 2004. Technological diversity of persistent innovators in Japan: Two case studies of large Japanese firms. *Research Policy*, 33: 531–549.

Ahuja, G. 2000. Collaboration networks, structural holes, and innovation: A longitudinal study. *Administrative science quarterly,* 45: 425–455.

Rosenkopf, L., & Almeida. P. 2003. Overcoming local search through alliances and mobility. *Management Science*, 49: 751–766.

Reuer, J. J., &Ragozzino, R. 2006. Agency hazards and alliance portfolios. *Strategic Management Journal,* 27: 27–43.

MacKay, P., &Phillips, G. M. 2005. How does industry affect firm financial structure? *Review of Financial Studies,* 18: 1433–1466.

DeFond, M. L., & Park, C. W. 1999. The effect of competition on CEO turnover. *Journal of Accounting and Economics,* 27: 35–56.

Phelps, C. C. 2010. A longitudinal study of the influence of alliance network structure and composition on firm exploratory innovation. *Academy of Management Journal*, 53: 890–913.

Bromiley, P. 1991. Testing a causal model of corporate risk taking and performance. *Academy of Management Journal,* 34: 37–59.

Greve, H. R. 2003. A behavioral theory of R&D expenditures and innovations: Evidence from shipbuilding. *Academy of Management Journal*, 46: 685–702.

David, P., Hitt, M. A., &Gimeno, J. 2001. The influence of activism by institutional investors on R&D. *Academy of Management Journal,* 44: 144–157.

Aiken, L. S., & West, S. G. 1991. *Multiple regression: Testing and interpreting interactions.* Thousand Oaks, CA: Sage.

Anderson, P., &Tushman, M. L. 1990. Technological discontinuities and dominant designs: A cyclical model of technological change. *Administrative Science Quarterly*, 35: 604–633.

Klepper, S., & Simons, K. L. 1997. Technological extinctions of industrial firms: an inquiry into their nature and causes. *Industrial and Corporate Change,* 6: 379–460.