"Product market competition and a firm's R&D investment: New evidence from Korea"

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PRODUCT MARKET COMPETITION AND A FIRM'S R&D INVESTMENT: NEW EVIDENCE FROM KOREA

Abstract

This study aims to examine the effect of product market competition on a firm's investments in research and development (R&D) and how this effect varies depending on the firm's internal corporate governance. This study employs the regression method to analyze the association between product market competition and a firm's R&D investment. Since product market competition works effectively as an external corporate governance mechanism that reduces agency problems and information asymmetry, this study hypothesizes that a competitive product market promotes R&D investments. Using 11,560 firm-year observations of Korean listed firms for 2001–2020, this study finds a positive association between product market competition and R&D investment. The result also shows this association is more pronounced for firms with weak internal corporate governance mechanisms. Furthermore, additional analysis shows that the effect of product market competition on a firm's R&D investment is stronger for firms in the low-tech industry. This study provides new insights on the inconclusive association between product market competition and a firm's R&D investment and practical implications that product market competition drives firms to invest in R&D.

Keywords	product market competition, R&D, external corporate governance, internal corporate governance, investment
JEL Classification	M40, G30, G34, L10

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INTRODUCTION

This study investigates the association between product market competition and a firm's research and development (R&D) investments. It is well established that a firm's technological improvement and innovation are the key factors that drive long-term economic growth, as well as the firm's future performance and sustainability (Kuznets, 1966; Romer, 1990; Schumpeter, 1939). Investments in R&D by firms have increased dramatically in recent decades due to the rapid development of technology. Additionally, the increasing importance of a firm's innovative activities and R&D investments has attracted the attention of both researchers and market participants.

Many studies seek determinants of a firm's investments in R&D, considering the significance of R&D investments in fostering long-term firm and economic growth. The literature shows that both firm-and market-level factors influence firms' R&D investments, such as firm size, financial health, ownership structure, market structure, and government regulations (AlHares, 2020; Baldi & Bodmer, 2018; Bhagat & Welch, 1995; Spulber, 2013). Among the various determinants of firms' R&D investments, the association between market structure and firms' R&D investments has been a central theme and has drawn considerable attention from both academics and regulators, since the association between market structure and firms' R&D investments could provide practical implications for business strategies and market policies.

There is much literature on the association between market structure and a firm's R&D investments. Specifically, many studies focus on the effects of product market competition or concentration on a firm's R&D activities to answer the question of whether market competitiveness promotes or depresses a firm's investments in R&D (Arrow, 1962; Blundell et al., 1995; Geroski, 1990; Gu, 2016; Nickell, 1996; Schumpeter, 1943). However, both theoretical and empirical studies on the association between market competition and a firm's R&D investments show mixed and conflicting results owing to the use of different theoretical models, empirical methods, and data limitations.

According to the literature, product market competition is an effective external governance mechanism that contributes to reducing information asymmetry and agency problems through the disciplinary threat of survival or failure to both executives and firms (Byun et al., 2012; Grullon & Michaely, 2007; Shleifer & Vishny, 1997). The literature on a firm's R&D investments indicates that corporate governance is also a key determinant of a firm's R&D activities (Dong & Gou, 2010; Honoré et al., 2015; Jia et al., 2019; Rodrigues et al., 2020; Yoo & Sung, 2015). They provide empirical evidence that corporate governance, such as board independence, ownership structure, and anti-takeover devices, significantly affects a firm's R&D investments by reducing agency problems and information asymmetry. Given that product market competition is an effective corporate governance mechanism that reduces information asymmetry and agency problems, product market competition is likely significantly associated with a firm's R&D investments.

The remainder of this paper is organized as follows. Section 1 provides a literature review and hypotheses development. The research design and methods are presented in Section 2. Section 3 discusses the study's results. Finally, the last section concludes the paper.

1. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

A large body of research shows that a firm's R&D investments and technological competencies are key factors of sustainability and long-term growth for both firms and economics (Honoré et al., 2015; Kuznets, 1966; Romer, 1990; Schumpeter, 1939). Furthermore, the rapid development of technologies and changes in the market environment make a firm's R&D investment even more important (Lv et al., 2019; Rodrigues et al., 2020). Thus, many studies seek to identify the key determinants of a firm's R&D investments.

Among various factors affecting a firm's R&D investments, prior research examines the association between product market competition and a firm's R&D investments. However, theoretical and empirical studies often show mixed and conflicting results. For example, Schumpeter's (1943) early theoretical research contends that higher market concentration and monopolies promote innovations by reducing uncertainty and creating stable cash flows to finance R&D investments. In contrast, Arrow (1962) shows the theoretical background that market competition promotes a firm's innovation. Moreover, Scherer and Ross (1990) document that competition is a key driver of a firm's innovation and growth because it induces firms to innovate to survive and prevents bureaucratic inertia, which discourages innovation.

Several empirical findings on the effects of various forms of market competition on a firm's R&D investments also show mixed results. Early research by Horowitz (1962) proves that competition discourages a firm's R&D investments. Similarly, Blundell et al. (1995), using a sample of UK-listed firms, show that market-dominant firms are more likely to innovate, indicating that lower market competition promotes a firm's innovation. Other studies, such as Kraft (1989) and Crepon et al. (2006), support the idea that there is a negative association between market competition and a firm's innovation activities. More recently, research by Gu (2016) argues that high market competition may reduce a firm's R&D investment because resources to finance a firm's R&D projects are more likely to be extinguished in a competitive market.

There are also several empirical studies supporting the idea that high product market competition positively affects a firm's R&D investments. Using UK data, Geroski (1990) provides evidence that high market concentration and monopoly power decrease a firm's innovation, implying that lower market competition discourages R&D activities. Nickell (1996) and Blundell et al. (1999) also support the positive association between product market competition and a firm's innovation. Similarly, recent research by Van Vo and Le (2017) proves that firms in a competitive market are more likely to invest in R&D projects to obtain a competitive advantage because highly competitive markets face more threats to exit from the market.

In summary, previous studies on the association between product market competition and a firm's R&D investments show mixed and conflicting results. Moreover, extant research focuses on the effect of product market competition on risk, uncertainty, rents, and resource allocation when analyzing and interpreting the effect of product market competition on a firm's R&D investments.

The success of R&D investments brings about large benefits and superior performance for firms. However, R&D investment is a long-term business activity with features of high uncertainty, risk, and low possibility of success (Driver & Guedes, 2012; Lv et al., 2019). In agency theory, shareholders are considered risk-neutral because they can spread their risks. However, managers are treated as risk-averse because their probabilities of turnover and compensation depend on firm performance. In addition, in agency theory, managers can only apply their efforts to one job. Therefore, managers prefer short-term gains derived from efficiency-seeking strategies, creating conflicts of interest between managers and shareholders. Information asymmetry also hinders shareholders from monitoring managers effectively and aligning managers' and shareholders' interests.

Collectively, the features of a firm's R&D investments and agency theory clearly imply that there are conflicts of interest between managers and shareholders in R&D investment decisions, since the purpose of managers is to maximize their own interests and secure their jobs. While the main objective of shareholders is to maximize the value of the firm, managers are more likely to underinvest.

Corporate governance refers to a set of internal and external disciplinary and control mechanisms that reduce conflicts of interest and information asymmetry between managers and shareholders, resulting from the separation of ownership and control (Shleifer & Vishny, 1997). Corporate governance comprises monitoring managers and incentives that reduce their self-serving behavior. A large body of research has documented that corporate governance promotes a firm's R&D investments by reducing agency problems and information asymmetry (Dong & Gou, 2010; Honoré et al., 2015; Jia et al., 2019; Rodrigues et al., 2020; Yoo & Sung, 2015).

For instance, Dong and Gou (2010) documented that managerial discretion, ownership structure, and independent outside directors are significantly associated with a firm's R&D investments. Similarly, Rodrigues et al. (2020) argue that board characteristics such as board size, independence, and tenure significantly affect a firm's R&D investments. AlHares (2020) also provides evidence that institutional ownership, board size, board independence, and board diversity are critical factors that affect a firm's R&D investments.

It is well established that product market competition is one of the most effective disciplinary corporate governance mechanisms that reduce information asymmetry and agency problems by aligning the interests of the managers with shareholders (Alchian, 1950; Griffith, 2001; Schmidt, 1997; Shleifer & Vishny, 1997).

For example, Griffth (2001) shows that managers are subject to higher default risk and turnover in a competitive market, forcing them to invest their best efforts. Thus, agency problems tend to decrease, and productivity increases. Similarly, Schmidt (1997) claims that a high level of product market competition significantly reduces managerial slack, motivating them to dedicate much more effort to survive in a competitive market.

Early research by Alchian (1950) indicates that high product market competition encourages firms to reduce production costs to lower the cost of capital and optimize corporate governance.

Similarly, Holmstrom (1982) provides a theoretical background that increases product market competition to discipline managers to minimize costs and reduce information asymmetry and transaction costs. Numerous studies also argue that only efficient firms survive when the level of product market competition is high (Chhaochharia et al., 2017; Nickell, 1996), indicating that product market competition forces managers to work harder to improve a firm's sustainability.

Recent studies provide empirical evidence supporting the idea that product market competition encourages managers to work for shareholders' interests. Allen and Gale (2000) argued that market competition is more effective corporate governance and disciplinary mechanism than internal corporate governance or external monitoring mechanisms. Guadalupe and Perez-Gonzalez (2010) provide evidence that an increase in product market competition decreases the private benefits of managerial control, which represents the magnitude of the conflict between managers and shareholders. This result supports Fama's (1980) contention that product market competition enhances corporate governance, as an increase in competition discipline optimizes the spending and allocation of resources.

Extant research on internal and external corporate governance supports the "substitution hypothesis" that there is a substitute association between external and internal corporate governance. For instance, Giroud and Mueller (2011) provide evidence that the effects of internal corporate governance on stock returns and firm value differ, depending on the level of market competition. They show that the effect of internal corporate governance on stock returns and firm value is either small or insignificant when market competition is high, and either large or significant when competition is low.

Kim and Lu (2011) examined the relationship between CEO ownership (internal corporate governance) and product market competition (external corporate governance) to show that there is a substitution effect in reducing agency problems. Grosfeld and Tressel (2001) provide evidence that a firm's internal corporate governance determines the effect of product market competition on firm performance.

This study aims to clarify the association between product market competition and a firm's R&D investments by focusing on the external governance role of product market competition. Based on the above arguments and literature reviews, this study conjectures that product market competition, as an effective external governance mechanism, promotes a firm's R&D investments. Furthermore, this study predicts that the association between product market competition and a firm's R&D investments differs depending on the firm's internal corporate governance, considering the substitute relationship between internal and external corporate governance mechanisms. Hence, the following hypotheses are proposed:

H1: *Product market competition is positively associated with R&D investment.*

H2: *The positive association between product market competition and R&D investment is more pronounced for firms with weak internal corporate governance.*

2. METHODOLOGY

2.1. Research design

This study investigates the association between product market competition and firms' R&D investments. To test hypotheses, this study extends previous research on firms' R&D investments and corporate governance (Dong & Gou, 2010; Honoré et al., 2015) by including product market competition as an independent variable. This study estimates the following regression model:

$$RD_{it} = \beta_0 + \beta_1 COMP_{it-1} +$$
$$+ \beta_2 PPE_{it-1} + \beta_3 SIZE_{it-1} +$$
$$+ \beta_4 ROA_{it-1} + \beta_5 LEV_{it-1} + \beta_6 CAPEX_{it-1} + \quad (1)$$
$$+ \beta_7 LNAGE_{it-1} + \beta_8 DIV_{it-1} + \beta_9 BTM_{it-1} +$$
$$+ \beta_{10} CASH_{it-1} + \sum IND + \sum YEAR + \varepsilon_t,$$

where *RD* captures the firm's R&D investments, measured by the firm's R&D expenditures scaled with the firm's initial total assets. *COMP*, the key independent variable in this study, captures product market competition. Specifically, product market competition is measured by

the Herfindahl-Hirschman Index (HHI), commonly used in previous research (Boubaker et al., 2018; Giroud & Mueller 2011; Gu, 2016). Tirole (1988) also supports the theoretical background using HHI to measure product market competition.

The study adds the squares of the individual market shares in the industry to calculate the HHI, calculated by dividing the firm's sales by the total industry sales. In Korea, private firms with total assets greater than ten million dollars must be audited by external auditors, allowing us to include the major private firms that are subject to external audits in addition to the public firms listed on the KOSPI and KOSDAQ (equivalent to NYSE and NASDAQ in the U.S.) when measuring the HHI. By including major private firms, HHI is complete and better reflects the industry than other HHIs that used only listed firms or higher-ranked firms in the industry (Byun et al., 2012; Giroud & Mueller, 2011; Grullon & Michaely, 2007). This study uses the three-digit Korea Standard Industry Classification (KSIC) code for industry classification to measure the HHI. Finally, the HHI is multiplied by –1, so a higher HHI reflects competitive industries.

Following previous literature (Bhagat & Welch, 1995; Dong & Gou, 2010; Honoré et al., 2015; Ren et al., 2020), this study also controls for various firm characteristics that could affect a firm's R&D investments, such as PPE (*PPE*), size (*SIZE*), return on assets (*ROA*), leverage (*LEV*), capital expenditures (*CAPEX*), age (*LNAGE*), dividend payment (*DIV*), book-to-market ratio (*BTM*), and cash holdings (*CASH*). Appendix A provides details and definitions of each variable. The study also controls for industry- and year-fixed effects and adopts the lead-lag test model by including lagged independent and control variables to address potential endogeneity issues.

The second hypothesis predicts that the positive association between product market competition and a firm's R&D investments will be stronger for firms with weak internal corporate governance mechanisms. Thus, this study divides the sample into subsamples to test the hypothesis based on board independence and foreign investor ownership, which represent a firm's internal corporate governance.

A body of literature has suggested that a board's actions are important in preventing managers' self-serving behavior (Rodrigues et al., 2020; Yoo & Sung, 2015). They argue that board independence is critical for improving a board's actions and monitoring functions. Board independence is enhanced when directors have no relationship with the company or managers (Rodrigues et al., 2020; Yoo & Sung, 2015). Thus, this study measures board independence as the proportion of outside directors on the board. This study then divides the sample into subsamples based on the proportion of outside directors. Firms with outside directors above the industry median are classified as having high board independence, which represents strong internal corporate governance.

In addition to board independence, the sample is divided into subsamples based on foreign investor ownership. Numerous studies show that foreign investor ownership is associated with corporate governance (DeFond et al., 2011; Kim et al., 2019; Leuz et al., 2010). They argue that higher foreign investor ownership is associated with better internal corporate governance (Leuz et al., 2010), comparability (DeFond et al., 2011), and audit quality (Kim et al., 2019). Thus, this study divides the sample by foreign investor ownership based on these findings to classify firms with strong or weak internal corporate governance.

2.2. Sample selection

This study uses data from listed Korean companies for 2001–2020. Financial data were obtained from the TS2000 and FnGuide databases, which are equivalent to Compustat in the U.S. This study excludes firms with fiscal year-ends other than December to ensure sample homogeneity and to control for the effect of fiscal year-end. Financial firms are also excluded because they have distinct industrial characteristics and financial reporting standards. Lastly, firms without financial data were excluded, generating a large sample of 11,560 firm-year observations.

3. EMPIRICAL RESULTS AND DISCUSSION

3.1. Results

Table 1 provides the descriptive statistics for each variable; this study winsorizes at the top and bottom 1% for each continuous variable. The mean and median of *COMP* were –0.1256 and –0.0772, respectively. The dispersion of *COMP,* such as 25% percentile and 75% percentile, and the standard deviation show values of –0.1692, –0.0360, and 0.1283, respectively, suggesting a normal distribution. Furthermore, the statistics for the dependent variable *RD* show the mean and median values of 1.3044 and 0.2772, respectively. The sample firms have a size of 25.7565, leverage of 0.4341, and return on assets of 0.0282, on average.

The correlation coefficients of the test variables are presented in Table 2. The correlations in Table 2 show that there is no significant correlation between *RD,* the dependent variable, and *COMP,* which represents product market competition. However, drawing accurate conclusions and test results on the association between product market competition and a firm's R&D investment based on correlation coefficients is difficult. Therefore, the regression results are presented in the following tables, considering all the variables employed in the analyses. Table 2 also shows that *COMP* significantly correlated with *PPE*, *SIZE*, *LEV*, *DIV,* and *BTM.* Moreover, the correlation coefficients between the control variables were not relatively high, suggesting that multicollinearity was not a major concern in our analyses.

Table 1. Descriptive statistics

Variable	N	Mean	Standard deviation	Median	25%	75%
RD	11,560	1.3044	2.2443	0.2772	0.0000	1.5648
COMP	11,560	−0.1256	0.1283	−0.0772	−0.1692	−0.0360
PPE	11,560	0.1885	0.1450	0.1609	0.0773	0.2692
SIZE	11,560	25.7565	1.7422	25.4795	24.5124	26.7256
ROA	11,560	0.0282	0.0871	0.0309	0.0047	0.0671
LEV	11,560	0.4341	0.2093	0.4350	0.2711	0.5808
CAPEX	11,560	0.1921	0.2380	0.1119	0.0528	0.2303
LNAGE	11,560	3.4886	0.6424	3.6636	3.2958	3.8918
DIV	11,560	0.7052	0.4560	1.0000	0.0000	1.0000
BTM	11,560	1.5764	1.2669	1.2509	0.7214	2.0227
CASH	11,560	0.0824	0.1012	0.0472	0.0156	0.1082

Note: (1) All variables are defined in the Appendix. (2) All continuous variables were winsorized at the top and bottom 1%. (3) All *p*-values are based on two-tailed tests.

Table 2. Correlations (*p*-values below)

Variable	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RD_{it} (1)	0.0028	(0.0650)	0.2300	0.0852	(0.0981)	0.0205	(0.0869)	0.0776	(0.1964)	0.0553
	0.7617	< .0001	< .0001	< .0001	< .0001	0.0277	< .0001	< .0001	< .0001	< .0001
$COMP_{it-1}$ (2)	–	(0.1381)	(0.2085)	(0.0102)	(0.1125)	(0.0068)	(0.0096)	0.0488	0.0215	(0.0013)
	–	< .0001	< .0001	0.2726	< .0001	0.4656	0.3026	< .0001	0.0208	0.8861
PPE_{it-1} (3)	–	–	0.0687	0.0637	0.2532	(0.0223)	(0.0172)	(0.0015)	0.0466	(0.0919)
	–	–	< .0001	< .0001	< .0001	0.0167	0.0648	0.8753	< .0001	0001
$SIZE_{it-1}$ (4)	–	–	–	0.2584	(0.1313)	(0.0209)	(0.0411)	0.2637	(0.4375)	(0.0086)
	–	–	–	< .0001	< .0001	0.0246	< .0001	< .0001	< .0001	0.3554
ROA_{it-1} (5)	–	–	–	–	(0.3260)	0.0722	(0.0919)	0.4594	(0.0691)	0.1952
	–	–	–	–	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
LEV_{it-1} (6)	–	–	–	–	–	(0.0954)	(0.0193)	(0.3603)	(0.0104)	(0.1118)
	–	–	–	–	–	< .0001	0.0378	< .0001	0.2624	< .0001
$CAPEX_{it-1}$ (7)	–	–	–	–	–	–	(0.0979)	0.0310	(0.0549)	0.0878
	–	–	–	–	–	–	< .0001	0.0009	< .0001	< .0001
$LNAGE_{it-1}$ (8)	–	–	–	–	–	–	–	(0.0072)	0.1171	(0.1102)
	–	–	–	–	–	–	–	0.4369	< .0001	< .0001
DIV_{it-1} (9)	–	–	–	–	–	–	–	–	0.0204	0.0397
	–	–	–	–	–	–	–	–	0.0285	< .0001
BTM_{it-1} (10)	–	–	–	–	–	–	–	–	–	(0.1066)
	–	–	–	–	–	–	–	–	–	< .0001
$CASH_{it-1}$ (11)	–	–	–	–	–	–	–	–	–	1.0000
	–	–	–	–	–	–	–	–	–	–

Note: (1) All variables are defined in the Appendix. (2) All continuous variables were winsorized at the top and bottom 1%. (3) All p-values are based on two-tailed tests.

Table 3 reports the empirical results for the first hypothesis, based on Equation (1). The coefficient of the variable of interest, *COMP* (0.6057), is positive and significant at the 1% level (p-value < 0.01), supporting the first hypothesis that there is a significant positive association between product market competition and a firm's R&D investments. Among the control variables, *PPE*, *SIZE*, *LEV*, *LNAGE*, and *BTM* are significantly associated with a firm's R&D investments, showing qualitatively consistent results with those of previous studies (Bhagat & Welch, 1995; Ren et al., 2020).

Table 3. Product market competition and a firm's R&D investments

Variable	Dependent variable = RD_t	
	Coef.	p-value
Intercept	−3.5751	< 0.01
$COMP_{it-1}$	0.6057	< 0.01
PPE_{it-1}	−1.0898	< 0.01
$SIZE_{it-1}$	0.2625	< 0.01
ROA_{it-1}	−0.0555	0.8412
LEV_{it-1}	−0.6984	< 0.01
$CAPEX_{it-1}$	−0.1432	0.0983
$LNAGE_{it-1}$	−0.2171	< 0.01
DIV_{it-1}	0.0161	0.7583
BTM_{it-1}	−0.2470	< 0.01
$CASH_{it-1}$	0.0374	0.8603
Industry fixed effect	YES	
Year fixed effect	YES	
Adj. R²	0.0964	
N	11,560	

Note: (1) All variables are defined in the Appendix. (2) All continuous variables were winsorized at the top and bottom 1%. (3) All *p*-values are based on two-tailed tests.

Table 4 reports the empirical results for the second hypothesis. The second hypothesis examines whether the effect of product market competition is stronger when a firm's internal corporate governance mechanisms are weak. To test the second hypothesis, this study divides the sample into subsamples to test the hypothesis based on board independence and foreign investor ownership.

Panel A of Table 4 shows the results when the sample is divided based on the board independence. The results indicate that the coefficient of *COMP* (0.7435, p-value < 0.01) is significant and positive at the 1% level for firms with weak internal corporate governance, whereas those with strong corporate governance are weak and insignificant (0.2265,

p-value = 0.2873). Furthermore, the coefficient of *COMP* in each group was statistically different (p-value < 0.01), supporting the second hypothesis that the association between product market competition and a firm's R&D investments is stronger for firms with weak internal corporate governance.

Panel B of Table 4 reports the subsample analysis based on foreign investor ownership. The results show that the coefficient of *COMP* (0.8377, p-value < 0.01) is significantly positive for firms with foreign investor ownership lower than the industry median. However, the coefficient of *COMP* (−0.0801, p-value = 0.7610) for firms with higher foreign investor ownership is not statistically significant, thus supporting the second hypothesis.

Table 4. The effect of internal corporate governance on the association between product market competition and R&D investments

	Panel A: The effect of board independence on the association between product market competition and a firm's R&D investments				
	Dependent variable = RD_t				Difference test
Variable	High board independence (Outside directors higher than industry median)		Low board independence (Outside directors lower than industry median)		
	Coef.	p-value	Coef.	p-value	
Intercept	−4.5160	<0.01	−1.6203	0.0554	
$COMP_{it-1}$	0.2265	0.2873	0.7435	**<0.01**	<0.01
PPE_{it-1}	−0.8566	<0.01	−0.6927	<0.01	
$SIZE_{it-1}$	0.2970	<0.01	0.2016	<0.01	
ROA_{it-1}	−0.0183	0.9610	0.0536	0.8832	
LEV_{it-1}	−1.0210	<0.01	−0.4836	<0.01	
$CAPEX_{it-1}$	−0.1500	0.2068	−0.0652	0.5572	
$LNAGE_{it-1}$	−0.1726	<0.01	−0.3680	<0.01	
DIV_{it-1}	−0.0656	0.3464	0.1022	0.1515	
BTM_{it-1}	−0.2217	<0.01	−0.1498	<0.01	
$CASH_{it-1}$	−0.2475	0.4055	0.0617	0.8192	
Industry fixed effect	YES		YES		
Year fixed effect	YES		YES		
Adj. R²	0.1533		0.163		
N	7,236		4,324		

Table 4 (cont.). The effect of internal corporate governance on the association between product market competition and R&D investments

Variable	Dependent variable = RD_t				Difference test
	High foreign investor ownership (over industry median)		**Low foreign investor ownership (below industry median)**		
	Coef.	p-value	Coef.	p-value	
Intercept	−1.8332	0.0124	−2.7860	< 0.01	
$COMP_{it-1}$	−0.0801	0.7610	0.8377	< 0.01	**< 0.01**
PPE_{it-1}	−0.9687	< 0.01	−0.6064	< 0.01	
$SIZE_{it-1}$	0.2251	< 0.01	0.2175	< 0.01	
ROA_{it-1}	0.7238	0.2161	−0.5357	0.0372	
LEV_{it-1}	−1.2273	< 0.01	−0.4114	< 0.01	
$CAPEX_{it-1}$	−0.3585	0.0200	0.0194	0.8248	
$LNAGE_{it-1}$	−0.1700	< 0.01	−0.3065	< 0.01	
DIV_{it-1}	−0.4062	< 0.01	0.1331	< 0.01	
BTM_{it-1}	−0.3743	< 0.01	−0.1250	< 0.01	
$CASH_{it-1}$	−0.1558	0.6724	−0.0415	0.8529	
Industry fixed effect	YES		YES		☐
Year fixed effect	YES		YES		☐
Adj. R²	0.1467		0.1599		
N	5,780		5,780		☐

Note: (1) All variables are defined in the Appendix. (2) All continuous variables were winsorized at the top and bottom 1%. (3) All *p*-values are based on two-tailed tests.

3.2. Discussion

The study finds a positive association between product market competition and a firm's R&D investments, suggesting that firms are more likely to make R&D investments when product market competition is high. The result of the study implies that market competition induces firms to innovate and obtain a competitive advantage by reducing agency problems. Firms in the competitive market are more difficult to survive. Thus, managers in competitive markets are more likely to put much more effort into enhancing a firm's sustainability, which leads to an increase in R&D activities. This finding is consistent with the previous studies supporting the positive association between product market competition and a firm's R&D investments, such as Blundell et al. (1999), Nickell (1996), Geroski (1990), and Van Vo and Lee (2017), who support the idea that market competition promotes a firm's R&D investments. The result contradicts studies conducted by Blundell et al. (1995), Crepon et al. (2006), and Gu (2016), who showed a negative effect of product market competition on a firm's R&D activities.

The results for the second hypothesis show that the positive association between product market competition and a firm's R&D investments is more pronounced for firms with weak internal corporate governance. Specifically, the results show such association is stronger for firms with low board independence and low foreign investor ownership, supporting the "substitution hypothesis" that argues there is a substitute relationship between external and internal corporate governance, suggested by Giroud and Mueller (2011), Grisfekd and Tressel (2001), and Kim and Lu (2011). This result also supports the argument that product market competition significantly affects a firm's R&D investments as an effective external corporate governance mechanism.

Collectively, the results confirm that product market competition, as effective external corporate governance, disciplines managers' investment in R&D to survive. It provides evidence that there is a substitute relationship between product market competition and a firm's internal corporate governance, and the effect of product market competition is determined by the firm's internal corporate governance mechanisms.

3.3. Additional analysis

Previous studies clearly state that the effect of product market competition on a firm's R&D investment could vary depending on the firm's technological competencies and industry type (Hu et al., 2017; Lee, 2009). Therefore, this study divides the sample into two subgroups, high-tech and low-tech, to investigate whether the effect of product market competition varies depending on the industry type.

This study classifies firms into high-tech and low-tech industries using the Standard Industrial Classification (SIC) code developed by Kile and

Table 5. The effect of product market competition on a firm's R&D investments based on the industry type

| Variable | Dependent variable = RD_t | | | | Difference test |
| | High-tech industry | | Low-tech industry | | |
	Coef.	p–value	Coef.	p-value	
Intercept	−6.0048	< 0.01	−2.8203	< 0.01	–
$COMP_{it-1}$	−0.2734	0.5048	2.3902	< 0.01	< 0.01
PPE_{it-1}	−1.6413	< 0.01	−0.9523	< 0.01	–
$SIZE_{it-1}$	0.4641	< 0.01	0.2176	< 0.01	–
ROA_{it-1}	0.9774	0.1618	−0.0712	0.7976	–
LEV_{it-1}	−0.4812	0.1147	−0.2887	< 0.01	–
$CAPEX_{it-1}$	−0.0831	0.6856	−0.2213	0.0127	–
$LNAGE_{it-1}$	−0.3954	< 0.01	−0.2032	< 0.01	–
DIV_{it-1}	0.2772	0.0593	0.0445	0.3801	–
BTM_{it-1}	−0.2962	< 0.01	−0.1837	< 0.01	–
$CASH_{it-1}$	−0.6805	0.2016	0.3049	0.1532	–
Industry fixed effect	YES		YES		–
Year fixed effect	YES		YES		–
Adj. R²	0.1413		0.0941		–
N	2,554		9,006		–

Note: (1) All variables are defined in the Appendix. (2) All continuous variables were winsorized at the top and bottom 1%. (3) All *p*-values are based on two-tailed tests.

Phillips (2009). The results in Table 5 indicate that the coefficient of *COMP* (2.3902, p-value < 0.01) is significantly positive and significant for firms in the low-tech industry, whereas the coefficient of *COMP* (–0.2734, p-value = 0.5048) in the high-tech industry is not statistically significant. Furthermore, the coefficients of *COMP* in each group were significantly different (p < 0.01).

Previous literature shows that gains due to innovation are high, especially when the level of R&D appropriability and the firm's R&D competence is low because firms can establish a temporary monopoly through R&D activities (Lee, 2009; Tingvall & Poldahl, 2006). Thus, firms in low-tech industries are more likely to invest in R&D when the product market is competitive.

3.4. Robustness test

Following Gu (2016), this study used an alternative measure to calculate the HHI to enhance the robustness of the results. Using the same procedure, this study constructs a HHI using a firm's assets. Table 6 presents the results of the study. The coefficient of *COMP_Asset* (0.5790, p-value < 0.01) is positive and statistically significant, show-

ing qualitatively consistent results with our main findings.

Table 6. Robustness test: Alternative measure of product market competition (HHI based on a firm's total assets)

| Variable | Dependent variable = RD_t | |
	Coef.	p-value
Intercept	−3.5535	<0.01
$COMP\_Asset_{it-1}$	0.5790	<0.01
PPE_{it-1}	−1.0656	<0.01
$SIZE_{it-1}$	0.2622	<0.01
ROA_{it-1}	−0.0740	0.7895
LEV_{it-1}	−0.7013	<0.01
$CAPEX_{it-1}$	−0.1342	0.1216
$LNAGE_{it-1}$	−0.2179	<0.01
DIV_{it-1}	0.0164	0.7535
BTM_{it-1}	−0.2456	<0.01
$CASH_{it-1}$	0.0486	0.8193
Industry fixed effect	YES	
Year fixed effect	YES	
Adj. R²	0.0941	
N	11,560	

Note: (1) All variables are defined in the Appendix. (2) All continuous variables were winsorized at the top and bottom 1%. (3) All *p*-values are based on two-tailed tests.

CONCLUSION

The purpose of this study is to investigate the association between product market competition and a firm's R&D investments by focusing on the external governance role of product market competition. Moreover, this study examines how internal corporate governance affects the effect of product market competition on a firm's R&D investment.

The main results of this study show that product market competition is positively associated with a firm's R&D investments, implying that market competition induces managers to invest in R&D. Moreover, the results state there is a substitute relationship between product market competition and internal corporate governance. This result supports the argument that product market competition is an effective external corporate governance mechanism that could substitute internal corporate governance. Additional analysis shows that the effect of product market competition on a firm's R&D investment varies depending on the firm's industry type by showing the stronger positive association between product market competition and a firm's R&D investment for firms in the low-tech industry.

These findings prove that product market competition is an effective corporate external governance mechanism that prevents managements' myopic behavior on a firm's R&D investments. The results also provide practical implications for investors and regulators that market policies encouraging market competition would be useful to drive firms to operate in a way to maximize a firm's long-term value by promoting a firm's R&D investments. Moreover, the result of additional analysis suggests that policymakers should consider an industry type when setting the policies regarding market structure. Collectively, the results of this study can help managers and regulators set business strategies and policies in areas related to market structure and competition.

AUTHOR CONTRIBUTIONS

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Formal analysis: Ilhang Shin.
Funding acquisition: Ilhang Shin.
Investigation: Hansol Lee.
Methodology: Ilhang Shin.
Writing – original draft: Hansol Lee.
Writing – review & editing: Hansol Lee.

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APPENDIX A

Table A1. Variable definitions

Variable	Description
RD	Research and development expenditure divided by the beginning total assets
COMP	Herfindhal-Hirschman Index measured as: $$\sum_{i=1}^{N} x_i^2 \cdot (-1),$$ where, x_i is the market share of sales of firm i among all firms within the same industry. A higher value of *COMP* indicates less concentrated industries or more competition among firms in the same industry
COMP_Asset	The same as *COMP* except that total asset is used instead of sales when calculating the market share
PPE	Ratio of net property, plant, and equipment to the beginning total assets
SIZE	The natural log of the market value
ROA	Return-to-assets ratio, calculated as the income before extraordinary items divided by the beginning total assets
LEV	Leverage ratio, calculated as the sum of long-term and short-term debts divided by total assets
CAPEX	Capital expenditures scaled by book value of total assets at the end of fiscal year *t*
LNAGE	Natural logarithm of one plus firm's age
DIV	1 if the company paid out dividends, otherwise 0
BTM	Book to market ratio
CASH	Cash and cash equivalents/Total assets