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Antecedents and Effects of R&D Concentration : An Analysis from the Perspective of the Structure-Conduct-Performance paradigm

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연구개발(R&D)집중도의 결정요인 및 영향에 관한 연구 : S-C-P 패러다임 관점에서의 접근

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This paper examines, from the perspective of the structure-conduct-performance (S-C-P) paradigm, the structural factors that determine R&D concentration in industries. The results are as follows. First, an industry's R&D concentration is directly related to its market concentration, R&D intensity, capital intensity, and technological opportunities. In contrast, the higher an industry's performance, the more likely the diffusion of R&D investment is for firms belonging to that industry. Second, an industry's R&D concentration has a positive effect on its market concentration but a negative effect on its performance, suggesting that governments should adopt R&D policies that would induce more firms to invest in R&D instead of focusing only on a few firms to enhance industry performance.

Keywords : Industry Performance, Market Structure, R&D Concentration, R&D Intensity, S-C-P(Structure-Conduct-Performance) Paradigm

1. Introduction

Previous studies of R&D have suggested that the distribution of R&D investment by firms in an industry is highly skewed and that many firms report no R&D investment [7, 21, 22]. Cohen and Klepper [7], who were the first to analyze the characteristics of distributions of R&D investment by firms in an industry, found that such distributions are unimodal and positively skewed. Similarly, Lee [22] found that such distributions are lognormal and depend on the unobserved R&D-related capability or technical competence of firms in an industry.[1] These findings imply that R&D investment is concentrated in only a few firms.

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1) Cohen and Klepper [7] referred to this as the unobserved R&D-related capability of firms in an industry.

In this situation, the government can consider two directions of R&D policy. One way is to adopt the R&D policy in order to reduce the asymmetries in R&D as much as possible. That is, the government may try to induce all firms to participate in R&D investment evenly by increasing the support to firms with low levels of R&D investment. In this way, the government aims to spread the R&D capabilities of the firms and to decrease the differences among firms. In contrast, the government may want to enlarge R&D support to those firms that are evaluated as having high efficiencies in their link between R&D investments and R&D success, irrespective of the asymmetries in R&D investments. In this situation, if some firm that invests much now is very efficient in R&D investment, then the government can increase the support to that firm, which may in turn result in an increase in the asymmetry.

Among the two policy directions mentioned above, we need to determine which one is more useful in the performance of an industry. This paper examines, through empirical analysis, how the R&D concentration of an industry affects that industry's performance. On the basis of the results of this research, we want to derive R&D policy implications.

This paper also empirically examines the economic factors that determine the R&D concentration phenomenon in industries and finds that R&D investment is concentrated in only a few firms. No study has systematically examined the determinants of R&D concentration, although government institutions in each country provide data on R&D concentration.[2] Accordingly, to close this gap in the literature, this study provides the first empirical analysis of the determinants of R&D concentration.

For this, we employ the structure-conduct-performance (S-C-P) paradigm, a well-known analytical tool in industrial organization research. According to the S-C-P paradigm, structural characteristics of industries such as market concentration, product differentiation, and capital requirements can determine the activity of firms with respect to pricing, R&D, advertising, and investment, which in turn can influence their performance in terms of efficiency, price-cost margins, and profits [3, 18, 35, 43]. In recent years, the S-C-P relationship has been viewed as an interdependent one requiring a simultaneous determination, not as a one-way causal relationship in the context of the so-called "new industrial organization." Therefore, the R&D concentration phenomenon in industries is influenced by the structural characteristics of industries and is expected to influence industry performance. Further, the degree of R&D concentration influences the market structure (e.g., market concentration) and may be influenced by industry performance. Because the market structure, the firm's conduct, and market performance are closely related, it is necessary to establish an empirical model that can effectively address the endogeneity problem associated with these structure and performance variables, which may influence (or be influenced by) the R&D concentration variable.

For this reason, this study regards market concentration and the market rate of return as the endogenous variables influencing the R&D concentration ratio [18, 41, 11, 31] and employs a simultaneous equation model composed of three regression equations using market concentration, R&D concentration, and market performance as the dependent variables. For the analysis of the determinants of R&D concentration, the study uses market concentration, R&D intensity, capital intensity, the industrial growth rate, the appropriability of technology, and technological opportunities as the market structure variables, and it uses the industry rate of return as the market performance variable.

The main empirical results obtained by using this simultaneous equation model are as follows : as an industry becomes more concentrated and its R&D intensity and capital intensity increase, R&D investment in that industry becomes concentrated in only a few firms. By contrast, as the industry rate of return increases, and as the technological opportunity of an industry expands, more firms invest in R&D. Further, as R&D investment in an industry becomes concentrated, the market becomes more concentrated, and the industry rate of return decreases. These results suggest that an industry's R&D concentration (a variable which indicates firms' conduct) is influenced by the industry's market structure and performance and vice versa, which is consistent with the S-C-P paradigm.

The results have some important implications for governments interested in developing policies on R&D investment. Industry performance increases as more firms invest in R&D. Thus, to enhance industry performance, governments should encourage more firms to invest in R&D instead of supporting only a few firms intensively.

The rest of this paper is proceeds as follows : Section

2) According to data on R&D investment in Korea, thefive largest firms accounted for 38.7% of total R&D investment by all firms in Korea in 2008. The top 10 firms accounted for 43.1%, and the top 20 for 48.4% (KISTEP, 2009).

2 provides a review of previous research and proposes a set of hypotheses based on the review. Section 3 discusses this study's data, sample, research model, and methodology. Section 4 presents the results of the empirical analysis, and Section 5 provides conclusions and some policy implications.

2. Literature Review and Research Hypotheses

2.1 The Concept of Industry R&D Concentration

Previous studies have typically focused on "R&D intensity" to explain the characteristics of R&D investment at the industry level. R&D intensity is defined as an industry's total R&D investment divided by its total sales volume : however, although R&D intensity can represent the level of an industry's overall R&D investment, it cannot explain why R&D investment tends to be concentrated in only a few firms belonging to that industry. For example, suppose that the R&D intensity is 10% for industries A and B that, whereas only one firm in industry A invests in R&D, all firms in industry B are equally involved in R&D investment. In this case, the capacity for future production is likely to increase only for the one firm in industry A, whereas it is likely to increase for almost all firms in industry B. Further, this is likely to lead to differences in industry performance. In such situations, if we consider only R&D intensity, we cannot reflect or measure the relative asymmetry in R&D investment between firms.

As mentioned above, the relative distribution as well as the average investment level is critical to explaining the characteristics of R&D investment in an industry, and thus, we introduce the "industry R&D concentration" variable to characterize the relative asymmetry in R&D investment between firms. Further, we define the "industry R&D concentration" ratio as the squared sum of each firm's R&D share.[3] This new variable (called "RHHI") can be viewed as a variant of the HHI (Herfindahl-Hirschman index), which has been widely applied to R&D investment.

There are two different ways to measure the degree of R&D concentration in an industry. The first method is to draw the relevant index from the distribution of each firm's R&D intensity (i.e., R&D amount relative to sales amount) in an industry [7, 22]. The second method is to get the index from the distribution of each firm's absolute R&D amount in that industry.

The RHHI index that we employ in this paper measures the R&D concentration by the latter method. The reason why we need to use the RHHI index is as follows. Let us consider one example. In an industry, there are two firms (firm 1 and firm 2) that participate in R&D investment. Suppose that the sales and R&D amount of firm 1 are 1,000 and 100 respectively. Also assume that the sales and R&D amount of firm 2 are 4,000 and 400, respectively. In this case, the R&D intensities of the two firms are identically 0.1. If we measure the R&D asymmetries of this industry by R&D intensities, it would be at a minimum since the two intensities are the same. Therefore, when we evaluate the R&D concentration based on the distribution of R&D intensities, there appears to be no asymmetry in R&D investments in the industry. On the other hand, the absolute R&D amounts of these two firms are different, which tends to result in a difference in R&D success. For example, the R&D success probability of firm 2 would be higher than that of firm 1 since firm 2 invests much more in R&D than firm 1. Therefore, it would be more appropriate to evaluate the R&D concentration based on distribution information about the absolute R&D amount, in order to figure out the degree by which a firm's R&D investment is related to actual technological innovation. For this reason, the RHHI index which is derived from the distribution of absolute R&D investments of firms seems to be suitable, especially when we are interested in the actual R&D success capability distribution in an industry which is also related with that industry's performance.

2.2 Determinants of Industry R&D Concentration

2.2.1 Market Concentration and Industry R&D Concentration

There are two key issues surrounding the relationship between markets and R&D investment. One issue involves the determination of whether monopolistic markets or competitive markets are more likely to induce R&D investment, which refers to the relationship between market concentration and R&D investment [14, 38, 39]. The other involves the determination of whether R&D investment is more likely for large or small firms, which refers to the relationship between

3) A firm's R&D share is its R&D investment divided by total R&D investment in the industry to which the firm belongs.

firm size and R&D investment [17, 19, 30, 32].

In this study, the issue of special interest is the determination of whether market concentration promotes the R&D concentration phenomenon. This issue reflects the relationship between firm size and R&D investment. If firm size has a positive relationship with R&D investment in an industry, then a positive relationship may exist between the industry's market concentration and R&D concentration.

The Schumpeter-Galbraith hypothesis about the relationship between firm size and R&D investment posits that large (or more efficient) firms are more likely to invest in R&D than small (or less efficient) firms [14, 38, 39] in that large firms are more likely to secure large-scale funding, engage in risk-taking behavior, and benefit from economies of scale in terms of R&D investment [17, 19].[4] On the other hand, the Scherer hypothesis suggests that R&D investment may decrease as firm size increases [30, 32]. Large firms may have fewer incentives for innovation in that their compensation for innovators' efforts is not certain, as a result of bureaucracy. Hence, small and medium-sized firms may be more likely to invest in R&D than large firms.[5]

Previous empirical studies of the relationship between firm size and R&D investment have found a positive relationship between R&D investment and firm size and no relationship between R&D intensity and firm size [6, 7, 12, 40]. In most industries, firms tend to engage in R&D activity only when their size is above some critical level. Even if R&D investment does not increase in proportion to firm size, it typically increases as firm size increases [6, 8, 34]. On the other hand, some studies suggest that firms' technological competence and the appropriability of R&D in terms of market share have a conditional role in the size and R&D relationship [23, 25]. If we adopt the Schumpeter-Galbraith hypothesis, which posits that R&D investment increases as firm size increases, then we may expect that R&D investment is likely to become concentrated in a few large firms as the market becomes more concentrated.

4) The "new Schumpeter hypothesis" refers to a situation in which a firm's R&D expenditure increases more rapidly than its size. Previous studies have reported that this relationship is strong when firm size is measured in terms of employment and weak when measured in terms of assets.

5) Rosenberg [30] reported a negative relationship between the market share and R&D expenditure per employee.

2.2.2 Barriers to Entry and Industry R&D Concentration

Barriers to entry into an industry represent a structural factor influencing the industry's market concentration [9, 20, 31]. The higher these barriers, the more likely the market concentration is because market entry for new entrants becomes more difficult. If large firms, which typically have more market power, have strong incentives for innovation, then R&D investment is likely to be concentrated in a few dominant firms.

An industry with high R&D intensity forms barriers to entry for potential entrants. For an industry whose firms are actively investing in R&D, new entrants must invest more in R&D to successfully enter that industry, which can further strengthen those barriers to entry. Thus, such industries are more likely to show high market concentration, which may lead to high R&D concentration in a few dominant firms [10, 11, 41, 42]. On the other hand, the opposing view suggests that technological innovation tends to increase competition and reduce market concentration by reducing the minimum efficient scale of production. That is, technological innovation may make the market structure more competitive by facilitating the imitation and adoption of technologies developed by other firms [4, 15]. In their empirical study of industries in the United Kingdom, Geroski and Pomroy [15] suggested that an increase in innovation reduces market concentration and an increase in market competition promotes innovation. In sum, R&D intensity can increase or reduce R&D concentration in that R&D investment may influence market concentration either positively or negatively, which makes the ex ante prediction of this relationship difficult. In this paper, we regard the above relationship as an economic issue requiring an empirical analysis and adopt the traditional S-C-P paradigm to investigate this issue.

Capital intensity indicates how much capital is required to produce a product. A capital-intensive industry needs a wide range of capital inputs such as production facilities and equipment because of the characteristics of its production processes [9, 13, 29, 31] to entry strengthen and thus it becomes more concentrated. Accordingly, because industries tend to be technology- or capital-intensive, technological innovation is likely to be led by a few large firms with some advantage in R&D and facilities [2].

2.2.3 Technological Characteristics and Industry R&D Concentration

An industry's R&D concentration may be influenced by its technological characteristics, including the appropriability of technology and technological opportunities. R&D results

reflect public goods, and thus the degree to which R&D results are protected influences the incentive for R&D investment [37, 26, 27]. The appropriability of technology indicates the degree to which the result of a product or process innovation is protected. In general, as the appropriability of technology increases, a firm's incentive for R&D investment increases [26]. Consequently, firms in an industry become more likely to invest in R&D, which may reduce R&D concentration. On the other hand, when the appropriability of technology decreases, a firm's incentive for R&D investment could decrease as well. In this case, incentives for R&D investment may be concentrated in a few large firms with a market base to which R&D results can be applied [8].

Also, technological opportunities can influence an industry's R&D concentration. "Technological opportunities" refers to the production possibility set that can transform research resources into new technologies and include the possibility of altering physical characteristics of products, in addition to the exogenous development of science and technology. Technological opportunities can vary considerably according to the industry [26, 33]. Because the R&D activity of a firm is influenced by technological opportunities in the industry to which the firm belongs, R&D concentration is influenced by technological opportunities. As technological opportunities increase, a larger number of firms are likely to be induced to participate in technological innovation. But there may be much difference between innovative incentive and actual R&D investment level among firms because the profit increase due to innovation is closely related with firms' characteristics such as firm size and marketing channels. Thus, the effect of technological opportunity expansion on R&D concentration is ambiguous ex ante. So, in this paper, we will examine this relation empirically.

2.2.4 Industry Growth Rate and Industry R&D Concentration

R&D investment involves a future-oriented, strategic decision-making process [5, 16]. When we examine R&D investment from the perspective of market demand, the expected rate of return increases as the market expands [36]. Thus, we anticipate that incentives for R&D investment are stronger for those industries with high growth rates. Further, the growth of an industry can diffuse and promote innovation, which can further induce R&D [34, 36, 41, 44]. Therefore, for a case in which the industry growth rate is high, R&D opportunities should increase, and as such, more firms are induced to invest in R&D, resulting in low R&D concentration even when R&D intensity is high.

2.2.5 Industry Performance and Industry R&D Concentration

For high-risk projects, it is difficult to procure necessary funds through capital markets. Therefore, an industry with a high rate of return has an advantage in securing funding for risky investments [39]. Because firms in industries with high rates of return are more likely to secure adequate funding, those industries tend to offer more opportunities for technological innovation [16]. Thus, when the rate of return for an industry is high, the industry is more likely to offer incentives for R&D investment in the future. For this reason, R&D concentration may decrease as more firms are induced to invest in R&D.

3. The Sample and the Research Model

3.1 The Sample

We obtained the industry data by using data on firms listed on Korea's Stock Exchange. Such a method is useful for determining an industry's R&D or market concentration and can overcome data limitations at the industry level.

We included 15 of the 24 industries belonging to the manufacturing sector. Nine industries were excluded because they were comprised by a very small number of firms. The industries of the manufacturing sector were selected based on a medium-level classification of the Korean Standard Industry Classification (KSIC). Each of these industries had at least 20 firms listed on the Korea Stock Exchange or KOSDAQ in 2008. <Table 1> presents these industries.

<Table 1> Distribution of the Sample by Industry

KSIC Code	Industry	Number of Firms in the Sample (2008)
C10000	Food and beverages	55
C13000	Textiles	29
C14000	Apparel	45
C17000	Pulp and paper products	34
C20000	Chemical products	105
C21000	Medical appliances and supplies	86
C22000	Rubber and plastics	42
C23000	Nonmetallic minerals	35
C24000	Basic metals	84
C25000	Fabricated metal products	50
C26000	Electronic components and communication equipment	363
C27000	Precision and optical instruments	44
C28000	Electronic equipment	72
C29000	Other machinery and equipment	142
C30000	Motor vehicles	78

We used a panel data set that spanned a 20 year period from 1989 to 2008. The firm-level data were obtained using the KIS-value from NICE Information Service Inc.

3.2 The Empirical Model

We developed the following models to empirically test the S-C-P relationships discussed in the previous section. We employed a three-stage least squares method to (a) examine the economic factors influencing R&D concentration (see Equation 1), (b) investigate the factors determining market concentration (see Equation 2), and (c) determine the factors influencing industry performance (see Equation 3).

For Equation 1 (i.e., the determinants of R&D concentration), we added the export ratio as well as the market structure and performance variables mentioned earlier. The export ratio for an industry was measured as its exports divided by its total sales. An industry with a high export ratio is more likely to be one where domestic markets are opened to foreign competitors than one with a low export ratio [31]. Therefore, the industry's R&D concentration may decrease in that more firms are induced to invest in R&D in order to meet the needs of foreign domestic markets.

For Equation 2 (i.e., the determinants of market concentration), we included advertising intensity [13, 29] and the minimum efficient scale [9, 13] as well as a structure variable (the growth rate), conduct variables (R&D intensity and R&D concentration), and a performance variable (the industry rate of return). Both advertising intensity (representing product differentiation) and the minimum efficient scale (measuring economies of scale) are variables for barriers to entry, which influence market concentration. For Equation 3 (i.e., the determinants of the industry rate of return), we added advertising intensity and the export ratio (as control variables) as well as structure variables (market concentration, industry growth rate, and capital intensity) and conduct variables (R&D concentration and R&D intensity).

$$RHHI = \alpha_0 + \beta_1 HHI + \beta_2 I_{per} + \beta_3 RND_{int} + \beta_4 CAP_{int} + \beta_5 Tech_{APP} + \beta_6 Tech_{oppor} + \beta_7 Growth + \beta_8 \mathrm{Export} + \varepsilon$$

$$HHI = \gamma_0 + \delta_1 RHHI + \delta_2 I_{per} + \delta_3 RND_{int} + \delta_4 Growth + \delta_5 ADV_{int} + \delta_6 \ln(MES) + v$$

$$I_{per} = \eta_0 + \theta_1 RHHI + \theta_2 HHI + \theta_3 RND_{int} + \theta_4 Growth + \theta_5 CAP_{int} + \theta_6 ADV_{int} + \theta_7 \mathrm{Export} + v$$

The operational definitions of the variables are summarized in <Table 2>. A measure of R&D appropriability of was constructed from the Korean Technology Innovation Survey [45], conducted by the Science and Technology Policy Institute (STEPI). The survey, which is a Korean version of the Yale Survey, examined various mechanisms, such as patents, secrecy, and lead time, that were available to protect firms' competitive advantage from innovation. A measure of industry technological opportunities was also constructed from the same survey. The survey examined the current rate of product and process technology advance in the industry. The lower the score of the measure is, the higher the technological opportunities in the industry are.

<Table 2> Definitions of Variables

Variable Name		Operational Definition
Dependent Variables	RHHI	R&D concentration ratio : The HHI of R&D investment (by industry and year)
	HHI	Market concentration ratio : The HHI by industry and year
	I_{per}	Industry rate of return : Total operating income/ total assets × 100 (by industry and year)
Independent and Control Variables	RND_{int}	R&D intensity ratio : Total R&D/total sales × 100 (by industry and year)
	CAP_{int}	Capital intensity ratio : Total fixed assets/ number of employees
	$Tech_{APP}$	Appropriability of technology : The degree to which technology is protected; ½ × (product innovation protection) + ½ × (process innovation protection) [24]
	$Tech_{oppor}$	Technological opportunities : the time it takes for product and process innovation; ½ × (the months taken for product innovation) + ½ × (the months taken for process innovation)
	Growth	Industry growth rate : The = currentyear'ssales/ previousyear'ssales
	ADV_{int}	Advertising intensity : Advertising expenditure/ total sales × 100
	Export	Export share of an industry : Total exports/total sales × 100
	$\ln(MES)$	Minimum efficient scale : The log value of firm size corresponding to 50% of total industry sales (Lyons, 1980)

4. Empirical Results

4.1 Descriptive Statistics and Correlation Analysis

<Table 3> and <Table 4> present the descriptive statistics and the results of the correlation analysis, respectively.

<Table 3> Descriptive Statistics for Independent Variables

Variable	Observations	Average	Standard Deviation	Minimum	Maximum
RND_{int}	315	0.52	0.78	0.01	4.45
CAP_{int}	315	212.58	184.05	9.89	1008.81
$Tech_{APP}$	315	3.48	0.24	2.91	3.93
$Tech_{oppor}$	315	31.65	15.73	10.39	78.08
Growth	300	12.28	12.67	-24.80	60.15
EXPORT	315	16.20	15.57	0.29	72.90
ADV_{int}	315	1.21	1.67	0.06	9.39
$\ln(MES)$	315	27.77	1.44	24.90	31.44

<Table 4> Correlation Analysis Results

Variable	1.	2.	3.	4.	5.	6.	7.	8.
1. RND_{int}	1.000							
2. CAP_{int}	0.110	1.000						
3. $Tech_{APP}$	-0.157**	-0.261**	1.000					
4. $Tech_{oppor}$	0.428**	0.433**	-0.135**	1.000				
5. Growth	-0.003	-0.133**	0.143**	0.076	1.000			
6. EXPORT	0.315**	0.218**	-0.264**	0.307**	-0.050	1.000		
7. ADV_{int}	0.238**	-0.316**	0.112**	0.007	-0.015	-0.288**	1.000	
8. $\ln(MES)$	0.240**	0.537**	-0.033	0.335**	0.117**	0.435**	-0.381**	1.000

Note) ** denotes significance at the 5% level.

4.2 Results from Empirical Analysis

4.2.1 Determinants of Industry R&D Concentration

<Table 5> shows the results obtained using the three-stage least squares method for the determinants of R&D concentration (RHHI). An increase in an industry's market concentration was found to increase its R&D concentration [40, 6, 8, 12].

An increase in an industry's R&D intensity was found to increase its R&D concentration.[6] As discussed in the section titled 'Barriers to entry and industry R&D concentration', high R&D intensity forms a barrier to entry into the industry for potential entrants, thereby increasing the industry's market concentration, which in turn can increase R&D concentration due to the positive relationship between firm size and R&D investment. Such a situation can occur in industries with high R&D intensity if there are R&D leaders dominating R&D investment and R&D followers investing smaller amounts in R&D.

<Table 5> The Three-Stage Least Squares Method for Determinants of Industry R&D Concentration

Independent Variable	Regression Coefficient (standard error)	z-value
HHI	1.079 (0.13)	9.07***
I_{per}	-230.483 (94.01)	-2.45**
RND_{int}	911.768 (205.602)	4.43***
CAP_{int}	4.241 (0.88)	4.80***
$Tech_{APP}$	-118.576 (411.80)	-0.29
$Tech_{oppor}$	-34.230 (11.78)	-2.91***
Growth	15.385 (15.65)	0.98
EXPORT	-18.914 (8.50)	-2.22**
Year Dummies	<Included>	
Observations	300	
R^2	0.198	
Significance level of the model (Wald x^2)	149.22***	

Note) The standard error is in parentheses. *** and ** denote significance at the 1% and 5% levels, respectively.

6) Lee and Noh [24] show that R&D concentration from the distribution of firms' R&D intensity, R&D appropriability and industry-wide technological opportunities jointly determine industry R&D intensity.

The results indicate that capital intensity had a positive effect on R&D concentration. In general, barriers to entry for potential entrants are high for industries with high capital intensity. For this reason, it is difficult for a firm to enter such an industry, which can increase the industry's market concentration. Hence, a few large firms tend to account for the vast majority of that industry's markets, and these firms are also likely to dominate R&D investment, thereby increasing the industry's R&D concentration.

The results found that the appropriability of technology had a negative effect on R&D concentration although the effect was not significant. In general, as the appropriability of technology increases, a firm's incentive for R&D investment increases [26]. As a result, firms in an industry become more likely to invest in R&D, which may reduce the industry's R&D concentration.

Industry-wide technological opportunities were found to be positively correlated to R&D concentration. The results suggested that the higher the technological opportunities in an industry, the higher the rate of technology advance and the more that industry's R&D is concentrated in a few firms. One plausible explanation is that, in an industry where the rate of technology advance is high due to the availability of more technological opportunities, large firms are likely to have more incentive for innovation than small firms because large firms have large production capacity and sale volumes to which new product or process technology can be applied. Thus, the potential increases in profit from the introduction of new technology would be greater for large firms than for small firms and the industry's R&D is likely to be concentrated in a few large firms. Another interpretation is that as the rate of technology advance increases, the expected lifetime of new technology shortens due to the competitive race of technological innovation, which entails the increased risk of technological obsolescence inherent in R&D investment. In such an industry, large firms are likely to invest more in R&D than small firms because they have an advantage over small firms in achieving economies of scale with respect to R&D activity, production, marketing, and financing as well as handling the risk of technological obsolescence that is inherent in R&D investment.

The results show that the industry growth rate had a positive effect on R&D concentration although the effect was not significant. As discussed in literature review, if the industry growth rate is high, firms are likely to have a positive view of the future return on R&D investment: however, large firms are likely to have more incentive to invest in R&D than small firms because large firms may enjoy potentially greater benefits from the introduction of new technology than small firms. In this study, however, the relation is not significant and additional evidence is needed to arrive at this conclusion. Industry performance is found to be positively correlated to R&D concentration. When the rate of return for an industry is high, the industry is more likely to offer incentives for R&D investment in the future. For this reason, R&D concentration decreases in that more firms invest in R&D.

4.2.2 Determinants of Market Concentration

The results we obtained using the three-stage least squares for the determinants of market concentration (HHI) are summarized in <Table 6>.

<Table 6> The Three-Stage Least Squares Method for Determinants of Market Concentration

Independent Variable	Regression Coefficient (standard error)	z-value
RHHI	0.278 (0.11)	2.47**
I_{per}	-206.879 (135.93)	-1.52
RND_{int}	-51.766 (134.59)	-0.38
Growth	41.420 (17.00)	2.44**
ADV_{int}	185.392 (140.61)	1.32
$\ln(MES)$	471.135 (118.69)	3.97***
Year dummies	<Included>	
Observations	300	
R^2	0.267	
Significance level of the model (Wald x^2)	126.94***	

Note) The standard error is in parentheses. *** and ** denote significance at the 1% and 5% levels, respectively.

As expected, we found that an industry's R&D concentration had a positive relationship with its market concentration. If an industry's R&D concentration is high, it is likely that there is substantial asymmetry in R&D investment size among firms in that industry. As a result, there are large differences among firms in terms of production efficiency and product/technology competitiveness. Hence, market concentration may increase in that differences in the market share increase. In general, previous studies have viewed the barrier to entry as the most important determinant of market

concentration. Although this kind of traditional entry barrier plays a crucial role in determining market concentration, the results of this study indicate that R&D concentration can also have considerable influence on market concentration. R&D is an investment behavior entailing costs in the present for increasing future returns through process or product innovation. Because each firm individually determines its own R&D level, R&D investment can be considered a conduct variable. Hence, this study makes an important contribution to the literature in that the results indicate that the distributional characteristics of an industry's R&D investment (i.e., conduct) can influence the distribution of the market share (i.e., the structure) of that industry.

The results show that an increase in an industry's R&D intensity reduced its market concentration, although the effect was insignificant. As discussed earlier, there are two opposite effects of R&D intensity on market concentration. One effect is that R&D intensity may increase market concentration by forming barriers to entry as a result of economies of scale in terms of R&D, and the other is that it may accelerate competition through technological innovation. Thus, the effect of R&D intensity on market concentration may vary according to the relative size of these two effects. The results of the present study provide support for the latter effect and are consistent with the Arrow hypothesis. In a market controlled by a monopoly, the result of technological innovation replaces one monopoly with another, making additional gains from innovation relatively small. By contrast, in a competitive market, increases in profits through innovation are very likely in that each firm starts with no excess profits. Thus, a firm in a competitive market is more likely to invest in R&D than a monopoly [4, 15]. When an industry is close to a competitive structure and therefore its market concentration is low, its R&D intensity is likely to be high.

The results show that the industry rate of return had a negative (but insignificant) effect on market concentration. As the industry rate of return increases, firms have more incentives to enter the industry [29]. Thus, as the industry rate of return increases, market concentration tends to fall as a result of new entrants. An industry's market concentration increased as its growth rate increased, which is inconsistent with the findings of previous studies [29], suggesting a negative relationship between the industry growth rate and market concentration arising from new market entrants. This result can be explained as follows. An industry with a high growth rate is one with large increases in sales from the increased demand. However, in this case, the increase in sales varies across firms. That is, the increase in sales for a low-cost firm with a large market share is likely to be greater than that for a high-cost firm with a small market share, which is likely to increase the industry's market concentration. The reason for this result is that low-cost firms that are more efficient are more likely to capture new opportunities provided by the increased demand than high-cost firms that are less efficient.

The results find that advertising intensity had a positive (but insignificant) effect on market concentration. It is well known that advertising intensity raises barriers to entry through product differentiation [13, 28, 29]. The minimum efficient scale (MES) was found to be positively correlated to market concentration. Because the MES is an output scale that determines the minimum average cost, it can reflect the size of barriers to entry associated with economies of scale. In general, as the MES for an industry increases, the output of incumbent firms in that industry increases as well. Thus, the equilibrium number of firms in the industry decreases, and the industry becomes more concentrated [13, 29].

4.2.3 Determinants of Industry Performance

The results obtained using the three-stage least squares method for the determinants of industry performance (I_{per}) are summarized in <Table 7>.

<Table 7> The Three-Stage Least Squares Method for Determinants of Industry Performance

Independent Variable	Regression Coefficient (standard error)	z-value
RHHI	-0.001 (0.00)	-2.05**
HHI	0.001 (0.00)	3.58***
RND_{int}	0.797 (0.41)	1.95*
Growth	0.095 (0.02)	4.81***
CAP_{int}	0.008 (0.00)	4.08***
ADV_{int}	0.874 (0.19)	4.67***
Export	-0.004 (0.02)	-0.27
Year dummies	<Included>	
Observations	300	
R^2	0.129	
Significance level of the model (Wald x^2)	154.10***	

Note) The standard error is in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

As an industry's R&D concentration increased, its performance decreased. As results for Equation 2 suggest, R&D concentration increased market concentration, which in turn influenced industry performance. When we controlled for this indirect effect, R&D concentration had a direct negative effect on industry performance. This result may be explained as follows. If an industry's R&D concentration is high, it is likely that there are large differences in R&D investment size among firms in that industry. Thus, such an industry typically has a few firms making large R&D investments and many firms making small ones [7, 22]. In general, the rate of return is high for firms making large R&D investments because of improvements in competitiveness, and that for firms making small R&D investments is low because of low efficiency. This represents a case in which the latter negative effect is greater than the former positive effect.

The results show that the market concentration had a positive effect on industry performance [1, 20, 31]. An industry with high market concentration is closer to a monopolistic structure than to a competitive structure. For this type of monopolistic market structure, firms in the industry are able to set a price above the marginal cost,[7] which increases the equilibrium price and the industry rate of return.

The results also show that R&D intensity had a positive effect on market performance [31, 41]. If an industry's R&D intensity is high, firms belonging to that industry are likely to make large R&D investments, which in turn has positive effects on industry performance through efficiency enhancements, productivity improvements, and technological advancements. On the other hand, the need for large R&D investments raises barriers to entry, which can increase market concentration and generate high rates of return.

Capital intensity was found to be positively correlated to the industry rate of return [20]. An industry with high capital intensity requires large production facilities, machinery, and equipment for production. Hence, barriers to entry into such an industry are high in that new entrants must make large investments to purchase various capital goods [9, 20, 31]. Thus, the industry is likely to have a more concentrated market structure and a higher rate of return. In addition, firms in such an industry have high capital equipment rate per production worker, which can enhance both labor productivity and market performance [20].

As found in previous studies, advertising intensity had a positive effect on the industry rate of return [11, 20]. An industry with high advertising intensity typically reflects a high degree of product differentiation. In such an industry, each firm obtains some market power for its own product, and thus the price is set above the marginal cost, resulting in a high rate of return for that industry. Furthermore, because barriers to entry into advertising-intensive industries are typically high, such industries typically maintain a monopolistic structure, and thus the industry rate of return is high. In addition, advertising shifts the market demand curve to the right and thereby raises the equilibrium price, which has a positive effect on market performance.

The results indicate that the industry growth rate had a positive effect on the industry rate of return [11, 20]. A high industry growth rate implies increased market demand, which increases both the equilibrium price and the rate of return. Because it takes a long time for new entrants to increase outputs through capacity expansion, incumbents can maintain a high rate of return. Further, for a growing industry, there is some likelihood that production efficiency would be enhanced through the emergence of a new product or process innovation. Thus, because of such characteristics of the demand and supply sides, industry performance is likely to be enhanced as the industry growth rate increases.

5. Conclusions and Policy Implications

This study examines the structural factors that determine an industry's R&D concentration from the perspective of the S-C-P paradigm and, through an empirical analysis, investigates the effect of R&D concentration on the market structure and industry performance. The main results are as follows. First, an increase in an industry's market concentration, R&D intensity, capital intensity and technological opportunities had a positive effect on R&D concentration : in contrast, an increase in the industry performance had a negative effect on R&D concentration. Second, an industry's R&D concentration had a positive effect on its market concentration, suggesting that the distributional pattern of an industry's R&D investment (i.e., conduct) can influence the distribution of market shares of firms in that industry. Third, an industry's R&D concentration had a negative effect on industry per-

7) This ability is referred to as "market power" or "monopoly power." In a monopolistic structure, there is a general tendency toward collusion, which can be easily sustained in that the industry has a small number of firms. Thus, higher prices are likely than at the competitive level.

formance, implying that an industry's distribution of R&D investment (i.e., R&D concentration) and level of R&D investment (i.e., R&D intensity) are important determinants of that industry's performance. This result also implies that government should adopt R&D policies that reduce the asymmetries of R&D investment level among firms in order to increase the industry performance.

This empirical study contributes to the literature by using the S-C-P paradigm to identify the economic factors that determine an industry's R&D concentration. The results suggest a multi-directional and interactive relationship among the structure, conduct, and performance of the industry. Specifically, an industry's R&D concentration (i.e., conduct) is likely to be influenced by the structure and performance of that industry and vice versa.

The results have important policy implications for R&D investment. An industry is more likely to show better performance when more of its firms invest in R&D than when only a few large firms dominate R&D investment. Accordingly, to enhance industry performance, governments should adopt R&D policies that would induce more firms to invest in R&D instead of focusing only on a few firms.

This study contributes to the literature by using the S-C-P paradigm to examine both the effect of an industry's structural characteristics on R&D concentration and the effect of R&D concentration on industry performance. However, the R&D concentration index used in this study has a limitation in that it does not incorporate the sales volume for each firm. Thus, future research should develop an appropriate method that could address this limitation.

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