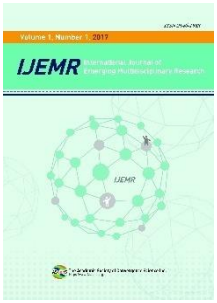

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A Study on the Determination of Export Activities of Korean Manufacturing Companies : Focused on R&D Activities

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Abstract

Background/Objectives: For this study, the 2018 Korean Innovation Survey (KIS) by Science and Technology Policy Institute (STEPI) was used to analyze the impact on the exports of Korean manufacturing companies. Methods/Statistical analysis: The analysis consists of two main themes. One is to look at the factors influencing the decision on the export by using the logit model, and the other is to look at the factors influencing the decision on the export by region in the major overseas markets and its marginal effects by using the multinomial logit model. Findings: According to our result, the factors influencing the exports of the companies were classified largely into factors of R&D activities, corporate and industrial characteristics, and government support benefits. As a result of the analysis, for the R&D activity factor, internal R&D activities, R&D investment per capita, and proportion of personnel dedicated to R&D activities were found out to have a statistically significant positive (+) effect on the export activity. Improvements/Applications: This study is meaningful in the way that the effects on the exports of Korean manufacturing companies were viewed through various R&D activities, corporate and industrial characteristics, and government support, and examined the differences in the results of each factor according to changes in the major overseas market.

Index Terms

Export, R&D activities, logit, Multinomial logit, KIS Data

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I. INTRODUCTION

Korea has a small open economy system with a large share of the total economy taken by trade. As an example, Korea's dependence on exports[2]is 37.5% as of 2017, which is third highest among the G20 countries after Netherlands (63.9%) and Germany (39.4%) (KOSIS, KOrean Statistical Information Service). Having a high export dependency means that a country's economy depends on exports. Therefore, the economies of the countries with high export dependency are highly likely to be shocked by the economic fluctuations of major trading countries or the global economic environment. One major case is the recent trade dispute between Korea and Japan leading to the restriction of export items, which immediately affected negatively on the economies of both countries. Therefore, maintaining export competitiveness of companies is an important issue.

If so, what constitutes export competitiveness? According to the previous study [1,2], the export competitiveness factors of the companies were largely classified into internal factors and external factors. First, internal factors are the flexible nature of individual companies that can be identified by company size, credit, brand awareness, product quality, design, and price competitiveness. Such internal factors may contribute to export competitiveness by the efforts of the company (product development, ensuring outstanding human resources and market, etc.). On the other hand, external factors are mostly fixed in nature that can be identified by the distance from the country of trade, culture and religion, and the structure of the competitive market. This requires big movements at the national level (national policy, intercountry diplomacy, etc.). Therefore, it is more effective for companies to consider flexible internal factors than the fixed external factors to improve export competitiveness.

Various internal factors vary in importance depending on the characteristics and environment of the individual company. Nevertheless, many companies consider product quality as the most important factor. It is due to the quality of the products having a direct impact on company image and brand name, and being connected to other internal factors (e.g, price competitiveness, market acquisition, etc.). If so, what is the most important factor in determining product quality? [3,4,5,6] asserted that the quality of the product is determined by the technical skills owned by the company, and such technical skills are determined by the R&D activities. This is due to corporate R&D activities accumulating the intangible knowledge stock, affecting the productivity of the company in addition to labor and capital[7].

With such a background, this study aims at how the R&D activities of the companies affect the export.[3] To date, most studies analyzing the R&D activities of the companies[8,9,10,11,12,13] focused on clarifying the correlation between them. On the other hand, some studies [14,15,16,17] have compared the export performance according to the R&D activities, but all of them analyzed the R&D activities on R&D investment only, and there were no studies that have compared the effect according to the export by the export destination countries. Unlike the previous studies, this study considered the diverse R&D activities of the companies (R&D cooperation activities, R&D dedicated personnel, R&D intensity, etc.). Also, for the factor that determines the export of the company, we tried to compare the differences in the results by analyzing the regional effects of the export market as well as the effects on all exports.[4]

This study consists of the following. Chapter II will cover previous studies, and Chapter Ⅲ will identify the model used in the analysis. In Chapter IV, the characteristics of the variables will be explained with the description of the data used in the study. Chapter V will describe the results of the empirical analysis, and Chapter VI will propose future research directions with the conclusions and considerations based on the research findings.

II. PREVIOUS STUDIES

A. R&D and Economy

OECD defined R&D as "creative activities to acquire new knowledge about every object, including knowledge of man, culture, and society, or make new achievements by using the already acquired knowledge." Also, the International Accounting Standards Board (IASC) defined "research" as unique and planned analysis performed to acquire new scientific and technical knowledge and understanding, and "development" as the method of applying the research achievements and other knowledge to new or improved materials, devices, products, manufacturing method, system or service production plan or design. [18] defined research as the exploration of new

[2]Dependence on exports is an indicator that shows how much one country's economy depends on exports, referring to the share of the export amount according to GNI.

[3] R&D activities cannot be referred to as the absolute factor in export performance. In reverse, the export of a company can lead the company's R&D activities better, and there may be a complementarity relationship between the company's R&D investment and export performance. Nevertheless in this study, the theoretical premise of the neo-factor proportional model and technology-gap model that R&D activities play an important role in the performance of the companies was accepted, and empirical analysis was performed assuming the model proposed by [31] as the basic framework of the analysis.

[4]This study largely consists of two main themes. The first theme uses the logit model to examine the factors of determining exports for all export destinations. The second theme uses the multinomial logit model to examine the factors that affect the export decision by regions in the major overseas markets and their marginal effects

knowledge and development as the technical activities which convert the research results or scientific knowledge into new products or processes. From this definition, we can see that R&D enables acquiring new knowledge and using that knowledge to actualize the technological innovation of new products and services. [19] explained these technological innovations by classifying into product innovations and process innovations. He defined developing new or improved products and services as product innovation, and the innovation of reducing the production cost per unit by increasing the production efficiency in the process of producing new products created by such product innovation as process innovation. Technological innovation by R&D refers to producing new products or producing products in a more efficient way, and by comparing the competitive strategy by [20], it can be described as follows. Michael Everett Porter presented strategies of differentiation, cost leadership and focusing[5]as the way to acquire competitiveness, and it can be interpreted as having the company provide different or cheaper products from the competitors to have the competitiveness. Through technological innovation, companies can develop new products and services to differentiate themselves from competitors and increase production efficiency. This can be said to be in line with Michael Everett Porter's competitive strategy and cost leadership strategy.

In economics, however, technological innovation is described as the shift of production function. If technological innovation is exogenous, the equivalence curve is moved to the left, either by moving up the production function or by enabling production per unit with fewer production factors. In other words, even if the same capital is injected through technological innovation, fewer production factors may be used to increase productivity or to produce the same amount of product. Furthermore, neo-Schumpeterian economics presupposes technological change as the fundamental force of economic change. In the traditional view, technology has only been identified as a quantitative relationship between input and output, but this school sees technological change as the most fundamental driver of economic change.

B. R&D and International Trade

In the theory of international trade in economics, the importance of technological change in the process of explaining the flow of international trade and international competitiveness was recognized relatively early compared to other disciplines. Among them, for the neoclassical model, the trade patterns were assumed to be caused by the productivity differences between countries. According to this theory, the trade pattern is determined by the differences in relative prices between countries, and that relative price differences come from the differences in production costs due to differences in factor endowment. In other words, not like the traditional production theory, the importance of other factors besides labor and property such as R&D human resource and R&D expenditure were emphasized.[6]

On the other hand, the neo-factor proportional model, the extension of the Hecksher-Ohlon's theory of factor endowment, presents the theory that the relative endowment of technological factors other than capital and labor determines trade patterns [21,22,23]. That is, the technology factor includes skilled labor, human capital, R&D expenditure, and R&D personnel, and emphasizes the importance of the different factors from the traditional factors of production. Therefore, this model asserts that the products with abundant production factors, such as human or material capital and technical factors, will have export competitiveness.[7]

In general, traditional factor ratio theory is assumed to have given technology, and the technological level is internationally the same. On the other hand, the neo-technology model emphasizes the importance of change over time, with differences in skills and knowledge levels between countries. Under this concept, three theories emerged in the international trade theory, centered on technical factors. First, it is the technology gap model by [24]. He said when new products and new processes are developed continuously in one country, the completed product by this will have a relatively technical comparative advantage compared to other countries. Therefore, even if there is no comparative advantage in terms of factor ratio or endowed resources, he asserted that the country that has acquired export competitiveness by focusing on technological innovation can export its products. He also said the technical comparative advantage is maintained only until when other countries copy the technology, and over time, the new technology spreads and the initial technological competitiveness is exhausted. But, the technology gap model cannot provide an explanation of the production in the country with a low initial cost when technological innovation occurs. The theory presented for this is the location theory of production by Hirsch and the theory of production life cycle by Vernon. Hirsch thought the new product due to technological innovation will be going through the systematic cycle of change in the technology, and explained where the product is produced. Also, Vernon denied the factor

[5]The focus strategy refers to focusing on specific buyer groups, production lines, or regionally limited markets, which we have not included for it was considered to be out of the scope of this research paper's arguments.

[6]It is possible on the premise that the influence of factors other than production factors is controlled.

[7]In this study, the company's technology level was used as a proxy variable of technology factor which determines export competitiveness.

ratio and cost leadership in determining the production of products, and said that new products are initially produced in the country of demand and exported to other countries.

Recently, the empirical analysis of the impact of R&D activities on exports has been made in several previous studies based on the above theory. [25] made an empirical analysis of 111 Israeli companies that received R&D investment grants by multiple regression analysis to find out the effect of R&D staff ratio on the export increase. [26] set the dummy variable on R&D investment on 535 Chinese manufacturing companies as descriptive variables and the dummy variable on the exports as dependent variables and ran a logistics regression analysis to analyze the effect. We have found out that the investment in R&D gives a significantly positive (+) effect on the export. [27] used the discriminant analysis of the data collected from the survey and Tobit regression to prove that the factor that has significant effect on the export to North America is basic research and product improvement, and the independent variables that have a significant effect on global exports except North America include technical knowledge intensity, applied research, and product development. Also, [28] found from the study on Spain manufacturers that the R&D investment compared to sales had statistically a significantly positive (+) effect, and [29] verified that from R&D investment on the export of Korea in the perspective of product differentiation, R&D investment had positive effect on the increase of labor productivity and the number of companies (diversity of the products) and the number of companies had positive effect on the export and economic growth.

Summarizing the abovementioned previous studies, R&D activities are analyzed to have effects on the export by making the companies accumulate knowledge, acquire product competitiveness by improving the quality of the products by technological innovation, and acquire firm-specific advantages that are unique to the company first.

Fig. 1. The relationship between R&D activities and export

III. ANALYSIS MODEL

A. *R&D and International Trade*

[30] have mentioned before that the entrance to the export market is determined by the company's revenue and expenses calculated by a multi-period model of exporting with entry costs. This is a theory that proves that if the company's current and expected revenues are greater than its current costs, it is more likely to enter the export market.

$$Y_{it} = \begin{cases} 1 & \text{if } \widehat{\pi_{it}} > C_{it} + N \cdot (1 - Y_{it}), \\ 0 & \text{Otherwise} \end{cases} \quad \textbf{(1)}$$

$$\text{where } \widehat{\pi_{it}} \equiv \gamma_{it}^{*} + \delta(E_t[V_{it+1}(\cdot)|\gamma_{it}^{*} > 0] - E_t[V_{it+1}(\cdot)|\gamma_{it}^{*} = 0]) \quad \textbf{(2)}$$

Roberts &Tybout explained this theory with equations (1) and (2). Y_{it}has the characteristics of an indicator variable that indicates export activity of t. $\widehat{\pi_{it}}$ is the expected return of t, and $\gamma_{it}^{*}$is the desired level of export revenues for the export earnings of t. Also, refers to the costs of entry for entry into the export market, δ refers to the time preference for expected utility, and$E_t[V_{it+1}(\cdot)|\gamma_{it}^{*}]$refers to the conditionally expected value function by using the information from t on the export.

Therefore, this study determined the input factors to be used in the empirical analysis based on the model proposed by Roberts &Tybout. The company's production capacity is closely related to TFP, capital usage, and labor usage. Therefore, the R&D activity factor was considered as the factor influencing production efficiency. Also, the revenue and employees were logged as surrogate variables for capital stock and labor stock, and the size of the company and the technology level were considered as the characteristics of the company and industry.[8] In addition, the analysis included the benefits of government support by referring to the results of previous studies [31,32] that can exercise great influence in corporate R&D investment decision.

B. *Analysis Framework*

The effect of R&D activities of the company on export was analyzed mainly by using the logit model and multinomial logit model.

First, the logit model was used to analyze the subject countries for export. This is the model mainly used when the dependent variable is discrete like the company's export variable.[9]The characteristic of this

[8]In general, tangible fixed assets or the amount invested in equipment are used for proxy variables, but in this study, revenue was used as proxy variables for capital stocks due to the limitations of analysis data.

[9]In general, when the dependent variable is discrete, probit model and logit model are used. However, probit model is theoretically more restrictive than the logit model in applying the random probability utility model because

model is to assume the cumulative probability distribution as a logistic distribution. Therefore, the estimation coefficient is calculated as log odds ratios, which makes it easy to interpret.

This is calculated by the following process. The latent variables affecting the export of individual companies shall be called Y*. In addition, the export market variable that is actually observed can be indicated as Y=1 for export companies and Y=0 for non-export companies. It can be expressed by the following formula (3)[33].[10]

$$\begin{cases} Y_i^* = X_i\beta + \epsilon_i \\ Y_i = 1(Y_i^* > 0) \end{cases} \quad \textbf{(3)}$$

In this study, we considered the R&D activity factors as explanatory variables in the equation (3), with detailed description variables of log revenue, and log revenue squared, log employees, log employees squared, business experience, technical level, company size, etc.

On the other hand, the probability of the individual company i exporting by using equation (3) is as follows in equation (4).

$$\Pr_{i\ \text{Export}} = P(Y_i = 1) = P(X_i\beta + \epsilon_i > 0) = P(X_i\beta > -\epsilon_i) \quad \textbf{(4)}$$

In equation (4), the probability of which the individual company i can select is calculated by the probability of which the error term $-\epsilon_i$ is accumulated to$X_i\beta$. Also, by assuming the probability distribution of the error term to the logistic distribution, the relationship between the export probability and covariates can be expressed as equation (5).

$$\Pr_{i\ \text{Export}} = \frac{e^{X_i\beta}}{1+e^{X_i\beta}} \quad \textbf{(5)}$$

Therefore, the logit model enables the identification of the probability of the Korean manufacturing companies, the subject of the analysis, to participate at the time of analysis and the effect of the covariates in the entry into the export market.

On the other hand, the multinomial logit model was used to find out the export effect by region according to the export destination countries. The multinomial logit model is useful for the company i finding out one market among the alternatives (j) of multiple export markets in determining the entry of export. Therefore, this study compares the effects of changes in the export market by applying this model.

The multinomial logit model uses the individual characteristics such as sales, business experience, and the size of the business to describe the selection of the alternative (market) of companies, [11] and this is expressed as Equation (6).

$$\Pr(Y_i = j|x_i) = \frac{e^{\beta_j' x_i}}{1+\sum_{K=1}^{J} e^{\beta_K' x_i}} \qquad j = 0,1,2,\cdots,J \quad \beta_0 = 0 \quad \textbf{(6)}$$

$$\ln L = \sum_{i=1}^{N}\sum_{j=0}^{J} d_{ij} \ln pr\,(Y_i = j) \quad \textbf{(7)}$$

The multinomial logit regression model can be defined as Equation (7) as the log likelihood equation. Here, d_ij, if the company i selects the alternative j, has the value of 1, and the value of 0 if not. If the log likelihood equation is maximized, the estimated coefficient according to the maximum likelihood estimation can be obtained. Also, the marginal effects on the company's characteristic variables can be found based on these results. The marginal effects of the characteristic variables on the probability of having the selected results appear are calculated by the partial derivative of the equation (6)[34,35].

$$\frac{\partial \Pr_j}{\partial x_i} = \Pr_j\left[\beta_j - \sum_{k=0}^{J} \Pr_k \beta_K\right] = \Pr_j\left[\beta_j - \bar{\beta}\right] \quad \textbf{(8)}$$

On the other hand, the odds ratios of the multinomial logit model are not affected by the presence of other alternatives. This follows the assumption that the error terms of the model are independent and the variance is constant. Such property is called the Independence of Irrelevant Alternative (IIA). [12] [36] said that the population estimates cannot be altered structurally even when excluding irrelevant choices in various alternative sets from the model. It is inefficient to exclude these choices, but this ensures consistency [37].

IV. DATA AND VARIABLES

A. *Data*

This paper adopts a questionnaires survey to For this study, Korean Innovation Survey (KIS) performed

multiple integrals of the normal distribution should be evaluated.

[10]Bernard & Jensen (2004) added $N \cdot (1 - Y_{it-1})$ column in the estimated model to estimate the cost of entering the export market (N). However, in this study, the cost to enter the export market could not be estimated because the companies that were subjects of the analysis were the companies that exported for three consecutive years and the domestic companies that did not. Therefore, the analysis of Eq. (2) could not be performed.

[11]The discrete choice model can be largely classified into the conditional logit model and multinomial logit model according to the characteristics of explanatory variables. The difference between these two models is that for conditional logit models, the nature of the selection alternatives must be known, whereas the multinomial logit regression model should consist only of the individual characteristic variables of all explanatory variables.

[12] IIA refers to the relative probability of choosing one among several alternatives is independent from other alternatives.

by Korea by Science and Technology Policy Institute (STEPI) in 2018 on the Korean manufacturing companies was used. STEPI began KIS in 2002 with the purpose of collecting detailed information on the technological innovation activities of the Korean companies. It is being conducted in the manufacturing and service sectors every two to three years. KIS was investigated on the basis of the Oslo Manual proposed by the OECD(2005), aiming at researching the innovations and comparing the countries. The sample population of KIS is based on the survey of businesses of KOSIS, including both corporate businesses with more than 10 regular employees and private businesses. In addition, KIS is divided into the current status and characteristics of the innovative activities of the domestic manufacturers, which makes it possible to micro-analyze the performance of various R&D activities of the companies.[13]

The purpose of this study is to examine the effects of the companies' R&D activities in determining the export, so only the companies in which the R&D activities and the exports could be identified were used for analysis. Therefore, companies in which the R&D activities and the exports cannot be identified were excluded. The pretreatment process for the subjects of analysis is as follows. First, we have selected the companies that have continuous export activities for three years (2015-2017) and the companies that have no export activities for three years (3,456 companies) among the total population of 3,500 companies. We have excluded the companies from which the revenue has not been added up in 2017 and the exports by region could not be identified. Also, although performing the R&D activities, the companies that have not responded about the expense of R&D activities or responded with a lack of logical consistency have been excluded. Following this, for this study, 2,876 companies excluding 624 companies with inaccurate information among 3,500 companies in 2018 KIS DB were selected for analysis.

Key Variables

The key variables used in the analysis largely comprise R&D activity factors, businesses and industry characteristics factors and government support benefit factors. First, the R&D activity factor refers to the resources invested in R&D activities with the companies' R&D activities. This is to find out whether the companies' R&D activities affected the quality improvement of the product thus played an important role in export as described. In this analysis, this was discussed by the R&D activity variables including all of the internal and external R&D activities.[14]In addition, for the resources used in R&D activities, human resource was calculated with the consideration of the costs invested in R&D activities. R&D intensity, R&D investment cost per employee, and the ratio of personnel working only for R&D were used as key variables.[15]

For the factors of company and industry characteristic, the unique characteristics of each company and the technical characteristics of each industry were taken into account. Legal company size, business experience, location in the Seoul Metropolitan Area, revenue, and the technology levels were used as the key variables. On the other hand, for the classification standards of technology level, the technology level classification for manufacturers officially announced by Korean standard industrial classification and OECD were compiled, then used. It is largely classified into advanced technology, high technology, medium technology, and low technology.[16]On the other hand, the standards applied for the technical classification are shown in Table 1 below.

Factors of benefits from government support mean whether a company has benefited from a wide range of government support. This is a dummy variable mainly according to government support, of which tax support, funding, financial support, human resource support, technical support, certification support, and purchase support were utilized.

TABLE 1. TECHNOLOGY LEVEL BY INDUSTRY OF KOREAN MANUFACTURING COMPANIES USING OECD CLASSIFICATIO N STANDARDS

Technology	Industry (Business Code)
Advanced Technology	Manufacturer of electronic components, computers, imaging, sound, and communication equipment (26)
	Manufacturer of medical substances and pharmaceuticals (27)
	Manufacturer of aircraft, spacecraft, and parts (313)

[13]It should be noted that KIS DB is lateral data, not panel data. Therefore, there is a limit to performing dynamic analysis considering time difference.

[14]The factors of R&D activities in this study follow the definition of '2018 KIS' of STEPI.

[15]'KIS' uses innovation costs as R&D costs. The cost of innovation in the survey refers to the cost spent on all innovation activities performed for the purpose of introducing innovation, regardless of the success or practicality of the innovation. This also includes the costs incurred for innovation activities that have been interrupted or failed. KIS specifically mentions that the innovation cost proposed by OECD consists of R&D costs, acquisition cost of external disembodiment technology and know-how, acquisition cost of embodiment technology, other preparation costs for product innovation or process innovation, preparation for organizational innovation, cost for marketing activities and job training (OECD, 2005).

[16]OECD manufacturing technology levels are categorized into four sections. The classification of technology category is ① Advanced technology business (4 businesses), ② High technology business (5 businesses), ③ Medium technology business (6 businesses), and ④ Low technology business (11 businesses).

Technology	Industry (Business Code)
	Manufacturer of medical substances and pharmaceuticals (21)
High Technology	Manufacturer of chemical substances and chemical products (20)
	Manufacturer of other machinery and equipment (29)
	Manufacturer of electrical equipment (28)
	Manufacturer of automobiles and trailers (30)
	Manufacturer of other transportation equipment (31) (except 313 and 311)
Medium Technology	Manufacturer of corks, briquettes and refined petroleum products (19)
	Manufacturer of rubber and plastic products (22)
	Manufacturer of non-metallic mineral products (23)
	Manufacturer of primary metals (24)
	Manufacturer of metal and mineral products (25)
	Shipbuilding ships and boards (311)
Low Technology	Manufacturer of food (10)
	Manufacturer of beverages (11)
	Manufacturer of tobacco (12)
	Manufacturer of textile products (13)
	Manufacturing clothing, garment accessories and fur products (14)
	Manufacturing leather bags and shoes (15)
	Manufacturer of wood and wood products (16)
	Manufacturer of pulp, paper and paper products (17)
	Printing and record duplication companies (18)
	Manufacturer of furniture (32)
	Manufacturer of other products (33)

Source: Korea Institute of Startup & Entrepreneurship Development (2013), "Definition of Technology Entrepreneurship and the Study on the Standardization Methods of the Scope"

TABLE 2. DESCRIPTION OF KEY VARIABLES

Key Variables		Description
Factors of R&D Activity	R&D activities	• Performance of R&D activities in the last three years (2015-2017) • R&D activities refer to the activities including mechanical equipment, training, and job training related to the R&D activities other than 1) Internal R&D, 2) Joint R&D, and 3) External R&D
	Internal R&D activities	• R&D activities (including the development of software to satisfy this condition) carried out internally to produce new knowledge or solve scientific technological problems
	External R&D activities	• R&D activities carried out by outsourcing contract by other companies or agencies for the same purpose as internal R&D
	R&D investment per capita	• R&D investment cost per capita as of 2017
	R&D intensity	• The ratio of R&D investment compared to revenue in 2017
	The ratio of personnel working only for R&D	• Ratio of personnel working only for R&D among permanent employees in 2017
Factors of Characteristics by Companies and Industries	Company size	• Size designated by law, classified as large, medium and small
	Location in metropolitan area	• Location of the company classified as metropolitan and non-metropolitan
	Business experience	• Business experience as of 2017
	Export amount	• Export amount in 2017
	Revenue	• Revenue in 2017
	Number of employees	• Number of employees in 2017
	Technology level	• Business in advanced technology, high technology, medium technology, low technology
Factors of Government Support Benefits	Tax support	• Tax exemption or deduction on research and human resource development and industrial technology
	Funding	• Receipt of subsidies and participation in national R&D projects
	Financial support	• Receipt of investment, loans, guarantees, technical financial support, technological evaluation related to guarantees, R&D guarantees, etc.
	Human resource support	• Receipt of human resource support, recruitment support, employment recommendations, dispatch, manpower training, invitations, technical manpower support center, etc.
	Technical support	• Receipt of technical support such as technical development, technology commercialization, technology transfer, patent strategy, infrastructure construction and utilization, etc.
	Certification support	• Company certification or technology product certification from the government
	Purchase support	• Receipt of public purchase, priority purchase recommendation, or designation of outstanding products from the government

*B. **Basic Statistics of Key Variables**[17]*

Table 3 shows the basic statistics of the key variables. [18] The companies were categorized into export companies and domestic companies according to their export status. The samples were classified into 808 with export experience (28.1% of the total sample) and 2,068 with no export experience (71.9%). The characteristics of each company by each factor are as follows.

First, most of the variables belonging to the R&D activity factor showed that export companies are more active than domestic companies. As an example, while 56.4% of export companies were performing R&D activities, 32.9% of domestic companies were performing R&D activities. And, also for internal R&D activities and external R&D activities, the percentages of export companies and domestic companies were 11.7% and 7.5%, respectively. From the viewpoint of R&D investment, R&D investment per capita and the proportion of personnel dedicated to R&D were found out to be twice higher in export companies compared to domestic companies. On the other hand, R&D intensity was recorded 2.8% higher for the domestic companies.

In the factors of corporate and industrial characteristics, export companies were found to have a higher proportion of large and medium companies than domestic companies. The difference was 2.5% for large companies and 22.2% for medium companies. For export companies, medium companies (68.1%) accounted for the largest portion, while for domestic companies, small companies (52.7%) accounted for the largest portion. On the other hand, in terms of technology level, advanced and high tech industries were 8.4% and 15.1% higher in export companies than domestic companies. On the other hand, middle and low tech industries were shown to be 12.6% and 10.9% higher in domestic companies than export companies. Therefore, we can see that the export companies focus on high-tech industries and domestic companies focus on low-tech industries. Also, the average business experience of the exporting companies was 21 years, approximately 4.2 years higher than domestic companies, and the revenue and the number of employees of the export companies were also bigger than domestic companies.

All variables belonging to the factors of government support benefits showed that export companies outweighed domestic companies. Especially, tax support showed the biggest difference of 30.1%. Such differences were found in the order of purchase support, funding, and financial support, and technical support showed the smallest difference of 9.9%. On the other hand, domestic companies use the certification support system the most among the government's support systems, at 50.0%.

Therefore, for the Korean manufacturing companies, there is less number of export companies than domestic companies, but we can find out that export companies utilize R&D activities, sales volume, company size, technology level, and government support system more.

Table 3. BASIC STATISTICS OF KEY VARIABLES: EXPORT COMPANIES AND DOMESTIC COMPANIES

Variable		Export Companies					Domestic Companies				
		frequency	Mean	Std. Err.	Min	Max	frequency	Mean	Std. Err.	Min	Max
R&D Activities	Proportion of R&D activities (%)	808	56.44	49.62	0	100	2,068	32.93	47.01	0	100
	Proportion of internal R&D (%)	456	94.96	21.91	0	100	681	83.26	37.36	0	100
	Proportion of external R&D (%)	456	26.1	43.96	0	100	681	18.65	38.98	0	100
	R&D investment per capita (100 million won/person)	456	0.02	0.05	0	0.873	681	0.01	0.03	0	0.446
	R&D intensity (%)	456	4.6	8.59	0.01	105.263	681	7.38	37.24	0.003	755
	Proportion of personnel dedicated to R&D (%)	808	10.82	11.76	0	85	2,068	5.62	9.89	0	100
	R&D investment (million won)	456	1,534.21	4,009.97	2	51,877	681	547.73	1,701.38	1	26,700
Factors of Characteristics by Companies and Industries	Proportion of large companies (%)	808	3.96	19.52	0	100	2,068	1.45	11.96	0	100
	Proportion of medium companies (%)	808	68.07	46.65	0	100	2,068	45.84	49.84	0	100
	Proportion of small companies (%)	808	27.97	44.91	0	100	2,068	52.71	49.94	0	100
	Proportion of metropolitan area (%)	808	47.03	49.94	0	100	2,068	50.82	50.01	0	100
	Proportion of non-metropolitan area (%)	808	52.97	49.94	0	100	2,068	49.18	50.01	0	100
	Business in advanced technology (%)	808	19.18	39.4	0	100	2,068	10.74	30.96	0	100
	Business in high technology (%)	808	49.51	50.03	0	100	2,068	34.38	47.51	0	100
	Business in medium technology (%)	808	18.56	38.91	0	100	2,068	31.19	46.34	0	100
	Business in low technology (%)	808	12.75	33.37	0	100	2,068	23.69	42.53	0	100
	Business experience (years)	808	21.05	11.59	5	72	2,068	16.94	9.73	5	64

[17] Due to limited space in the research paper, basic statistics of export companies by regions are presented in <Appendix 1> and <Appendix 2>.

[18] The basic statistics in Table 3 are presented by converting all variables to percentage for the reader's convenience.

Variable		Export Companies					Domestic Companies				
		frequency	Mean	Std. Err.	Min	Max	frequency	Mean	Std. Err.	Min	Max
	Revenue (million won)	808	58,323	142,000	533	2,160,785	2,068	19,570	91,101	50	3,400,000
	Number of employees (persons)	808	114.96	174.13	10	2,894	2,068	49.61	75.68	10	1,511
Factors of Government Support Benefits	Tax support (%)	808	72.03	44.91	0	100	2,068	41.93	49.36	0	100
	Funding (%)	808	58.79	49.25	0	100	2,068	38.78	48.74	0	100
	Financial support (%)	808	53.84	49.88	0	100	2,068	37.48	48.42	0	100
	Human resource support (%)	808	54.08	49.86	0	100	2,068	39.80	48.96	0	100
	Technical support (%)	808	56.31	49.63	0	100	2,068	46.37	49.88	0	100
	Certification support (%)	808	60.03	49.02	0	100	2,068	49.95	50.01	0	100
	Purchase support (%)	808	51.73	50	0	100	2,068	37.33	48.38	0	100

V. ESTIMATION RESULTS

A. Factors Affecting Export Decisions of Korean Manufacturing Companies

Table 4 shows the analysis results of the factors affecting the export decision of Korean manufacturing companies by using the logit model. We analyzed a total of six models around the main parameters of the R&D activities.[19] As a result, R&D activities and internal R&D activities acted as statistically significant positive (+) factors in the export of the companies. And, R&D investment per capita and the proportion of personnel dedicated to R&D also acted as positive factors in the companies' exports. On the other hand, the external R&D activities and R&D intensity did not have a statistically significant effect on the company's export performance.

The log revenue of the company and industry characteristics factors showed statistically significant positive (+) signs only in Model (2), Model (3), and Model (4). On the other hand, the log business experience and metropolitan area acted as statistically significant positive (+) factors in export only in Model (1) and Model (6). This seems to be due to the difference between the subject of analysis by the models, and means that the company's business experience and the location in the groups that perform R&D activities (Model (2), Model (3). and Model (4)) is not related to export. For the technology level, advanced technology industries were found out to have a more positive effect on the export than other technologies (medium technology, low technology). On the other hand, the size of the company, log revenue squared, log number of workers, and the log number of workers squared generally did not show significant results in the export decision.

For the factors of government support benefit, benefits in tax incentives and purchase support acted as statistically significant positive (+) factors in decision on export by the companies. On the other hand, benefits in technical and certification support showed statistically significant negative (-) relationship in the export of companies. And, benefits in funding, financial support, and human resources support show positive signs, but were found out to be not statistically significant.

Table 4. FACTORS AFFECTING EXPORT DECISION OF KOREAN MANUFACTURING COMPANIES: LOGIT MODEL

Variable		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
Factors of R&D Activities	R&D activities	0.57*** (0.10)					
	Internal R&D activities		0.80*** (0.27)				
	External R&D activities			0.27 (0.17)			
	R&D investment per capita				3.43* (1.92)		
	R&D intensity					-0.0010 (0.0017)	
	Personnel dedicated to R&D Proportion						0.0284*** (0.0052)
Factors of Characteristics by Companies and Industries	Log revenue	0.47 (0.40)	1.17* (0.65)	1.17* (0.66)	1.14* (0.65)	1.11 (0.70)	0.45 (0.40)
	Log revenue squared	-0.01 (0.02)	-0.05 (0.03)	-0.05 (0.03)	-0.05 (0.03)	-0.05 (0.04)	-0.01 (0.02)
	Log number of employees	0.34 (0.41)	0.48 (0.65)	0.47 (0.65)	0.58 (0.65)	0.53 (0.67)	0.57 (0.43)
	Log number of employees squared	-0.01 (0.05)	-0.00 (0.08)	-0.00 (0.08)	-0.01 (0.08)	-0.01 (0.08)	-0.03 (0.05)
	High technology	-0.12 (0.15)	-0.20 (0.20)	-0.19 (0.20)	-0.25 (0.20)	-0.25 (0.20)	-0.01 (0.15)
	Medium technology	-0.71*** (0.17)	-0.70*** (0.24)	-0.71*** (0.24)	-0.75*** (0.24)	-0.75*** (0.24)	-0.51*** (0.17)
	Low technology	-0.94*** (0.18)	-1.26*** (0.25)	-1.31*** (0.25)	-1.31*** (0.25)	-1.33*** (0.25)	-0.71*** (0.18)
	Log business experience	0.38*** (0.09)	0.02 (0.14)	0.02 (0.14)	0.02 (0.14)	0.02 (0.14)	0.39*** (0.09)
	Medium companies	0.42 (0.32)	0.54 (0.45)	0.53 (0.45)	0.52 (0.46)	0.53 (0.46)	0.46 (0.32)
	Small companies	0.47 (0.35)	0.65 (0.49)	0.66 (0.49)	0.66 (0.49)	0.66 (0.50)	0.55 (0.34)
	Location in metropolitan area	0.23** (0.10)	-0.07 (0.15)	-0.05 (0.15)	-0.06 (0.15)	-0.06 (0.15)	0.22** (0.10)
Factors of Government	Tax support	0.86*** (0.13)	0.79*** (0.19)	0.81*** (0.19)	0.84*** (0.19)	0.83*** (0.19)	0.85*** (0.13)

[19] In each model, the differences in the results according to R&D activities were compared in as much detail as possible. In model (1) and model (6), both the companies that performed R&D activities and the companies that did not perform R&D activities were included. And in Model (2), Model (3), and Model (4), only the companies that performed R&D activities were analyzed.

Variable		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
Support Benefits	Funding	0.22 (0.15)	0.28 (0.20)	0.25 (0.20)	0.25 (0.20)	0.27 (0.20)	0.18 (0.15)
	Financial support	0.05 (0.16)	-0.10 (0.23)	-0.10 (0.23)	-0.12 (0.23)	-0.12 (0.23)	0.04 (0.16)
	Human resource support	-0.04 (0.17)	0.28 (0.24)	0.28 (0.24)	0.29 (0.24)	0.30 (0.24)	-0.04 (0.17)
	Technical support	-0.51*** (0.17)	-0.59*** (0.23)	-0.64*** (0.23)	-0.61*** (0.23)	-0.60*** (0.23)	-0.33* (0.17)
	Certification support	-0.32* (0.17)	-0.55** (0.23)	-0.52** (0.23)	-0.55** (0.23)	-0.55** (0.23)	-0.24 (0.17)
	Purchase support	0.40** (0.20)	0.47* (0.25)	0.48* (0.25)	0.52** (0.26)	0.50* (0.25)	0.30 (0.20)
Constant term		-7.46*** (1.66)	-9.98*** (2.86)	-9.41*** (2.81)	-9.38*** (2.79)	-9.10*** (2.98)	-8.14*** (1.66)
Number of companies		2,876	1,137	1,137	1,137	1,137	2,876

Note 1) ( ) is the standard error.
2) *, ** and *** mean that there is significance at the 1%, 5%, and 10% levels, respectively.

B. Factors Affecting Export Decision Due to Changes in Overseas Main Markets: Centered on R&D Activities

The export effect due to the change in the overseas main market was analyzed by using the multinomial logit model. The multinomial logit model tested the IIA condition of the model by HM test prior to the analysis. HM test determines the test quantity based on the estimated coefficients between the two models of having both the default and alternative solutions, and removing one alternative solution.

Table 5 shows that most models used in the analysis did not reject the null hypothesis due to having high significance probability, and the HM test statistic following the chi-square distribution showed a negative value. Therefore, the IIA condition of the multinomial logit model was satisfied.

Table 5. HM Test Statstics Results By Multinomial Logit Model

Model	Key Variables	Alternative 1 removed	Alternative 2 removed	Alternative 3 removed	Alternative 4 removed
(1)	R&D activities	1.71 (1.0000)	0.73 (0.9813)	2.38 (0.7939)	-1.57 (1.0000)
(2)	Intemal R&D activities	1.12 (1.0000)	-0.60 (1.0000)	-1.02 (1.0000)	0.30 (1.0000)
(3)	Extemal R&D activities	0.95 (1.0000)	-0.30 (1.0000)	-0.22 (1.0000)	-0.24 (1.0000)
(4)	R&D investment per capita	1.25 (1.0000)	-0.46 (1.0000)	-2.51 (1.0000)	-0.33 (1.0000)
(5)	R&D intensity	-0.57 (1.0000)	0.09 (1.0000)	-0.01 (1.0000)	-1.25 (1.0000)
(6)	Ratio of personnel dedicated to R&D	-3.60 (1.0000)	-0.03 (1.0000)	0.01 (0.9964)	-0.49 (1.0000)

Note 1) H0: difference in coefficients not systematic
2) ( ) is the significance probability.

The analysis results by using the multinomial logit model are presented in Table 6. First, R&D activities showed a statistically significant positive (+) effect in all regions. And in terms of the size of the estimated coefficients, it was in the order of other markets, Asian, North American, and European markets. However, the sample size used in the analysis is too small to generalize the interpretation of the estimated results.

Results of internal and external R&D activities by analyzing only the companies that performed R&D activities (1,137 pieces) are as follows. First, internal R&D activities showed statistically significant positive (+) relationship in advancing to the Asian, European and North American markets. The statistical significance was highest for the Asian market, and the size of the coefficient value was high in the Europe market. As for the external R&D activities, advancing showed a significantly positive (+) relationships only in the North American market and other markets.

R&D investment per capita showed statistically significant descriptions only in the Asian and other markets excluding the European and North American markets. On the other hand, R&D intensity did not show statistically significant results in any market. The personnel dedicated to R&D showed significant results in all overseas markets except for other markets, and the size of the coefficient values was in the order of North America, Asia, and Europe.

On the other hand, the estimated coefficients of the factors of companies and industry characteristics and the factors of government support benefits showed somewhat similar results to the logit model. The description of the analysis results is as follows.

Looking at the factors of the company and industry characteristics, revenue and the number of employees showed positive (+) relationship with export activities, and the companies belonging to the advanced technology regardless of the company size showed a significantly positive (+) relationship with the export activities. Also, the company's business experience and the location in the metropolitan area did not affect export activities.

For factors of government support benefits, benefits such as tax incentives, funding, human resources support, and purchase support generally showed a positive (+) relationship in the export activities of the company. However, statistical significance was found to be high only in the benefits of tax support and purchase support. The reason for using tax support and funding system showing positive (+) relationship in export is that by using such systems, it can directly reduce the production cost of the companies or the profit of the company by subsidies can affect the export activities. On the other hand, benefits such as financial support, technical support, and certification generally showed a negative (-) relationship in the export activities of the company. However, financial support was not statistically significant. The certification support system signifies the support of the acquisition of certification for highly competitive

products in Korea. Therefore, if the Korean government's certification is not valid in overseas markets, the benefits in the company's certification support may not play an important role in securing export competitiveness. In addition, since the technical support system provides technical guarantee and financial support to companies by technical valuation, it does not seem to affect short-term export activities even if the company becomes eligible for benefits.

Table 6. FACTORS AFFECTING EXPORT DECISIONS DUE TO CHANGES IN OVERSEAS MAIN MARKETING: MUTINOMIAL LOGIT MODEL

Model	Name of Variable	N	Asia	Europe	North America	Others
(1)	R&D activities	2,876	0.56***	0.47**	0.56**	1.35**
(2)	Internal R&D activities	1,137	0.80***	1.82*	1.27*	-0.51
(3)	External R&D activities	1,137	0.17	-0.05	0.79**	1.17*
(4)	R&D investment per capita	1,137	3.31*	3.25	2.72	9.45***
(5)	R&D intensity	1,137	-0.0010	-0.0305	0.0005	0.0007
(6)	Proportion of personnel dedicated to R&D	2,876	0.0285***	0.0264***	0.0340***	0.0127

Note: *, ** and *** mean that there is significance at the 1%, 5%, and 10% levels, respectively.

Table 7 is the marginal effect which the R&D activities affect on the probability of selection by regions in advancing to overseas markets. The marginal effects of R&D activity factors showed statistically significant results in R&D activities, internal R&D activities, and the personnel dedicated to R&D. Also, the factors of the R&D activities of these companies differed by regions in the export probability of the main overseas markets.

Looking at the results above in detail, the probability of Korean manufacturing companies choosing the domestic market was found out to be 9.1% lower if they perform R&D activities. On the other hand, the probability of choosing the Asian market was found out to be 6.3% higher, whereas the North American market is 1.0% higher and other markets 0.95% higher. But when performing internal R&D activities, the probability of choosing the domestic market was found out to be 16.5% lower. And in signs, the probability of choosing the Asian, European, North American and other markets by internal R&D activities shows positive (+) effect, but the statistical significance was found out to be low.

R&D activities and internal R&D activities of the companies were seen as statistically significant by showing a negative effect on the probability of the company's exports. The marginal effects on the probability of selecting the Asian market and other markets were also statistically significant. Also, the marginal effect of the personnel dedicated to R&D showed statistically significant effects only in the domestic, Asian and North American markets. Looking more closely, the marginal effect on the proportion of personnel dedicated to R&D in Korean manufacturing companies is as follows. As the number of personnel dedicated to R&D increases, the probability of choosing the domestic market will become 0.45% lower, whereas the Asian market is 0.32% higher and the North American market is 0.07% higher.

Table 7. MARGINAL EFFECTS BY REGIONS DUE TO CHANGES IN OVERSEAS MAIN MARKETS

Model	Name of Variable	Domestic	Asia	Europe	North America	Misc.
(1)	R&D activities	-0.091*** (-5.72)	0.063*** (4.20)	0.008 (1.05)	0.0104 (1.43)	0.0095* (2.28)
(2)	Internal R&D activities	-0.165** (-3.28)	0.080 (1.48)	0.060 (1.31)	0.036 (1.05)	-0.010 (-1.18)
(3)	External R&D activities	-0.047 (-1.50)	0.012 (0.40)	-0.009 (-0.58)	0.032 (2.21)	0.012 (1.41)
(4)	R&D investment per capita	-0.630 (-1.50)	0.431 (1.20)	0.062 (0.34)	0.043 (0.29)	0.093 (1.94)
(5)	R&D intensity	0.0007 (0.85)	0.0004 (0.49)	-0.0013 (-1.01)	0.0001 (0.28)	0.0000 (0.47)
(6)	Proportion of personnel dedicated to R&D	-0.0045*** (-6.34)	0.0032*** (5.26)	0.0005 (1.61)	0.0007** (2.65)	0.0000 (0.17)

Note: 1) The delta method was used to calculate the standard error.
2) The null hypothesis is as follows. H_0: Marginal Effect (ME) = 0)
3) *, ** and *** mean that there is significance at the 1%, 5%, and 10% levels, respectively.

VI. CONCLUSION AND IMPLICATION

This study examined the effects of R&D activities of the Korean manufacturing companies on exports. This was analyzed mainly in two ways. One was to look at the factors influencing the decision on the export by using the logit model, and the other was to analyze the factors influencing the decision on the export by regions in major overseas markets and its marginal effects by using the multinomial logit model.

Here are the major results of the analysis. R&D activities of the Korea manufacturing companies acted as a positive (+) factor in the export of the companies. Especially, the internal R&D activities of the Korean companies showed statistically significant positive (+) effects in exporting, but the external R&D activities did not show statistically significant results. Meanwhile, the personnel dedicated to R&D and R&D investment per capita in the perspective of labor and investment cost both showed statistically significant positive (+) effects.

The export effect by regions in major overseas markets was presented by considering the differences in the market changes between the companies focusing on the domestic market and the companies advancing to the overseas markets. As a result, the R&D activities of Korean manufacturing companies showed statistically significant positive (+) effects on all markets, and the internal R&D activities showed statistically significant positive (+) effects on entering the Asian, European and North American markets excluding the other markets. In particular, the external R&D showed a statistically significant positive (+)

effect only in North America and other markets. This is because the degree of external R&D cooperation among Korean manufacturing companies is important in North America compared to other regions.

The implications of this study are as follows. First, a market environment to expand the companies' R&D investment is needed. According to the study results, various R&D activities performed by the Korean manufacturing companies acted as positive factors for exports. Especially, R&D investment among many R&D activities exercised the greatest influence in advancing to the overseas market. Therefore, it is necessary to create a market environment in which companies can stimulate R&D investment. In response, the government should expand tax support and funding out of all of its support projects that act as a positive factor in export, and the companies should make the effort to improve the factors that hinder the promotion of R&D investment on their own. Also, it seems necessary to introduce a policy that provides more benefits to the R&D projects that are performed in the long term so that the R&D investment of the company does not end in one session.

Second, the elevation strategy in the technology level is required to acquire export competitiveness. According to the basic statistics that categorize the export companies and domestic companies of Korean manufacturing companies, the companies that have been exporting continuously for the past three years are found to have a high proportion of handling advanced technology and high technology. On the other hand, domestic companies had a high proportion of medium and low technologies. Also, we have found out that the advanced technology level in the determination of empirical analysis results and exports by using the logit model had a positive effect on exports compared to other technologies (medium technology, low technology). This is in line with the premise of the study that technological advancement is related to the improvement of product quality in terms of technological innovation, which is a positive factor for export. Therefore, individual companies need to devise an R&D strategy to upgrade their technology levels to acquire export competitiveness. On the other hand, the solution for this is to have active internal and R&D activities, which provides a positive effect on the export.

Third, export competitiveness should be acquired by selection and focus. Even if R&D activities are active, it is difficult to achieve effective export performance without better information in specific markets. Therefore, this study classified major overseas markets of Korean manufacturing companies by regions and examined the differences in export effects. This can be a useful criterion for determining which R&D activities or what areas should be prioritized in entering a particular overseas market. Therefore, the study implicates that the companies should understand the differences according to overseas markets and devise a better market strategy considering various input factors (including internal and external factors) before entering the market.

Finally, the parts of shortcomings and supplementation in this study which we can choose are the imperfection of the data. The KIS data used in this study has significance in the sense that all information related to the company's R&D activities, government support system, and major overseas markets are organized systematically. However, since it was survey data, there were a considerable number of missing values in the data used as variables, and the sample size was greatly reduced because only the companies with export performance in the last three years were used as subjects. Since this data is cross-sectional data, not panel data, dynamic analysis using time lag could not be performed.

This study is meaningful in the way that the effects on the exports of Korean manufacturing companies were viewed through various R&D activities, corporate and industrial characteristics, and government support, and examined the differences in the results of each factor according to changes in the major overseas market. However, the dynamic analysis could not be made due to the lack of data which enables time analysis. This remains as a study to pursue in the future.

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<Appendix 1> Basic Statistics of Major Companies in Asian & European Markets

Variable		Major Companies in Asian Markets					Major Companies in European Markets				
		frequency	Mean	Std. Err.	Min	Max	frequency	Mean	Std. Err.	Min	Max
Factors of R&D Activities	Proportion of R&D activities (%)	584	56.34	49.64	0	100	101	54.46	50.05	0	100
	Proportion of internal R&D (%)	329	94.83	22.17	0	100	55	98.18	13.48	0	100
	Proportion of external R&D (%)	329	24.92	43.32	0	100	55	21.82	41.68	0	100
	R&D investment per capita (100 million won/person)	329	0.02	0.05	0	0.87	55	0.01	0.03	0	0.17
	R&D intensity (%)	329	4.68	8.69	0.01	105.26	55	3.06	3.16	0.09	11.49
	Proportion of personnel dedicated to R&D (%)	584	11.05	11.75	0	85	101	9.77	10.59	0	50
	R&D investment (million won)	329	1,429.82	3,309.09	2	30,650	55	2,032.66	7,049.23	20	51,877
Factors of Characteristics by Companies and Industries	Proportion of large companies (%)	584	3.94	19.47	0	100	101	3.96	19.60	0	100
	Proportion of medium companies (%)	584	65.75	47.49	0	100	101	78.22	41.48	0	100
	Proportion of small companies (%)	584	30.31	46.00	0	100	101	17.82	38.46	0	100
	Proportion of metropolitan area (%)	584	45.38	49.83	0	100	101	54.46	50.05	0	100
	Proportion of non-metropolitan area (%)	584	54.62	49.83	0	100	101	45.55	50.05	0	100
	Business in advanced technology (%)	584	19.86	39.93	0	100	101	16.83	37.60	0	100
	Business in high technology (%)	584	50.00	50.04	0	100	101	49.51	50.25	0	100
	Business in medium technology (%)	584	18.15	38.58	0	100	101	19.80	40.05	0	100
	Business in low technology (%)	584	11.99	32.51	0	100	101	13.86	34.73	0	100
	Business experience (years)	584	21.01	11.61	5	72	101	20.75	11.02	5	53
	Revenue (million won)	584	58,262	154,000	533	2,160,785	101	64,288	127,000	1,000	885,100
	Number of employees (persons)	584	112.90	182.45	10	2,894	101	132.54	181.65	10	1,422
Factors of Government Support Benefits	Tax support (%)	584	71.75	45.06	0	100	101	74.26	43.94	0	100
	Funding (%)	584	59.42	49.15	0	100	101	60.40	49.15	0	100
	Financial support (%)	584	53.25	49.94	0	100	101	56.44	49.83	0	100
	Human resource support (%)	584	53.25	49.94	0	100	101	55.45	49.95	0	100
	Technical support (%)	584	56.85	49.57	0	100	101	59.41	49.35	0	100
	Certification support (%)	584	61.13	48.79	0	100	101	56.44	49.83	0	100
	Purchase support (%)	584	52.40	49.99	0	100	101	53.47	50.13	0	100

<Appendix 2> Basic Statistics of Major Companies North American & Other Markets

Variable		Major Companies in Asian Markets					Major Companies in European Markets				
		frequency	Mean	Std. Err.	Min	Max	frequency	Mean	Std. Err.	Min	Max
Factors of R&D Activities	Proportion of R&D activities (%)	99	58.59	49.51	0	100	24	58.33	50.36	0	100
	Proportion of internal R&D (%)	58	96.55	18.41	0	100	14	78.57	42.58	0	100
	Proportion of external R&D (%)	58	36.21	48.48	0	100	14	28.57	46.88	0	100
	R&D investment per capita (100 million won/person)	58	0.02	0.03	0	0.15	14	0.02	0.04	0	0.13
	R&D intensity (%)	58	3.68	7.07	0.02	49.973	14	12.62	18.23	0.06	49.68
	Proportion of personnel dedicated to R&D (%)	99	11.28	13.53	0	80	24	7.75	8.51	0	35
	R&D investment (million won)	58	1,711	4,034	2	26,431	14	1,292	2,68	2	10,007
Factors of Characteristics by Companies and Industries	Proportion of large companies (%)	99	5.05	22.01	0	100	24	0.00	0.00	0	0
	Proportion of medium companies (%)	99	73.74	44.23	0	100	24	58.33	50.36	0	100
	Proportion of small companies (%)	99	21.21	41.09	0	100	24	41.67	50.36	0	100
	Proportion of metropolitan area (%)	99	43.43	49.82	0	100	24	70.83	46.43	0	100
	Proportion of non-metropolitan area (%)	99	56.57	49.82	0	100	24	29.17	46.43	0	100
	Business in advanced technology (%)	99	18.18	38.77	0	100	24	16.67	38.07	0	100
	Business in high technology (%)	99	45.46	50.05	0	100	24	54.17	50.90	0	100
	Business in medium technology (%)	99	20.20	40.36	0	100	24	16.67	38.07	0	100
	Business in low technology (%)	99	16.16	37.00	0	100	24	12.50	33.78	0	100
	Business experience (years)	99	22.32	11.93	5	66	24	18.21	12.02	5	44
	Revenue (million won)	99	61,066	88,874	900	434,582	24	23,391	50,329	604	251,784
	Number of employees (persons)	99	120.23	126.81	10	825	24	69.17	65.31	10	300
Factors of Government Support Benefits	Tax support (%)	99	76.77	42.45	0	100	24	50.00	51.08	0	100
	Funding (%)	99	61.62	48.88	0	100	24	25.00	44.23	0	100
	Financial support (%)	99	62.63	48.63	0	100	24	20.83	41.49	0	100
	Human resource support (%)	99	64.65	48.05	0	100	24	25.00	44.23	0	100
	Technical support (%)	99	58.59	49.51	0	100	24	20.83	41.49	0	100
	Certification support (%)	99	64.65	48.05	0	100	24	29.17	46.43	0	100
	Purchase support (%)	99	54.55	50.05	0	100	24	16.67	38.07	0	99

<Appendix 3> Results of Multinomial Logit Model Regression Analysis (R&D Activities & Internal R&D Activities)

Variable	R&D Activities				Variable	Internal R&D Activities			
	Asia	Europe	North America	Others		Asia	Europe	North America	Others
R&D activities	0.56(0.11)***	0.47(0.23)**	0.56(0.23)**	1.35(0.56)**	Internal R&D activities	0.80(0.30)***	1.82(1.05)*	1.27(0.75)*	-0.51(0.62)
Log revenue	0.76(0.44)*	-0.13(0.88)	-0.58(0.76)	2.16(3.33)	Log revenue	1.43(0.71)**	0.04(1.27)	2.76(1.63)*	1.88(3.45)
Log revenue squared	-0.02(0.02)	0.02(0.04)	0.04(0.04)	-0.11(0.18)	Log revenue squared	-0.06(0.04)*	0.00(0.06)	-0.10(0.08)	-0.13(0.19)
Log number of employees	0.09(0.45)	0.49(1.00)	1.53(0.81)*	1.60(2.34)	Log number of employees	0.13(0.71)	0.95(1.43)	0.97(1.44)	5.63(4.10)
Log number of employees squared	0.01(0.05)	-0.01(0.11)	-0.14(0.09)	-0.17(0.27)	Log number of employees squared	0.03(0.08)	-0.02(0.16)	-0.09(0.15)	-0.60(0.51)
High technology	-0.15(0.16)	0.03(0.33)	-0.11(0.32)	-0.14(0.63)	High technology	-0.18(0.22)	-0.19(0.42)	-0.09(0.42)	-0.42(0.79)
Medium technology	-0.78(0.18)***	-0.46(0.38)	-0.50(0.37)	-1.05(0.72)	Medium technology	-0.73(0.26)***	-0.31(0.49)	-0.61(0.49)	-1.89(1.20)
Low technology	-1.05(0.19)***	-0.63(0.39)	-0.66(0.38)*	-0.98(0.86)	Low technology	-1.35(0.27)***	-1.58(0.62)**	-0.79(0.51)	-0.89(0.93)
Log business experience	0.40(0.10)***	0.26(0.20)	0.58(0.20)***	-0.07(0.40)	Log business experience	0.03(0.15)	0.01(0.33)	0.30(0.31)	-0.70(0.63)
Medium companies	0.35(0.36)	0.74(0.60)	0.33(0.57)	13.28(0.75)***	Medium companies	0.33(0.49)	0.75(0.72)	1.79(1.21)	10.91(0.88)***
Small companies	0.52(0.39)	0.25(0.69)	0.20(0.64)	13.17(0.97)***	Small companies	0.42(0.54)	0.48(0.88)	2.46(1.31)*	11.14(0.80)***
Location in metropolitan area	0.29(0.11)**	-0.05(0.23)	0.45(0.23)*	-0.90(0.48)*	Location in metropolitan area	-0.01(0.17)	-0.33(0.33)	0.16(0.32)	-1.15(0.55)**
Tax support	0.83(0.15)***	1.00(0.32)***	0.88(0.30)***	0.77(0.56)	Tax support	0.84(0.21)***	0.86(0.46)*	0.69(0.42)*	0.27(0.62)
Funding	0.31(0.16)*	0.18(0.35)	0.00(0.29)	-0.47(0.69)	Funding	0.38(0.22)*	0.41(0.40)	-0.11(0.35)	-0.55(0.78)
Financial support	-0.03(0.18)	0.17(0.40)	0.55(0.30)*	-0.57(0.65)	Financial support	-0.18(0.25)	-0.52(0.45)	0.69(0.36)*	-0.44(0.82)
Human resource support	-0.15(0.19)	-0.23(0.34)	0.66(0.36)*	0.23(0.59)	Human resource support	0.12(0.26)	0.36(0.44)	1.21(0.49)**	0.42(0.75)
Technical support	-0.51(0.19)***	0.07(0.37)	-0.87(0.37)**	-1.22(1.14)	Technical support	-0.41(0.25)	-0.24(0.48)	-1.58(0.47)***	-1.64(1.14)
Certification support	-0.26(0.19)	-1.08(0.41)***	-0.04(0.37)	-0.23(0.68)	Certification support	-0.59(0.25)**	-1.08(0.48)**	0.20(0.47)	-0.90(0.52)*
Purchase support	0.52(0.22)**	0.56(0.43)	-0.20(0.43)	-0.15(0.90)	Purchase support	0.51(0.28)*	0.68(0.49)	0.00(0.47)	1.08(0.98)
Constant	-8.72(1.83)***	-6.74(3.56)*	-7.76(3.49)**	-30.46(15.44)**	Constant	-10.63(3.06)***	-8.51(5.43)	-26.08(6.75)***	-29.00(20.22)
Observations	2,876	2,876	2,876	2,876	Observations	1,137	1,137	1,137	1,137

Note: 1) ( ) is the standard error.
2) *, ** and *** mean that there is significance at the 1%, 5%, and 10% levels, respectively.

<Appendix 4> Results of Multinomial Logit Model Regression Analysis (External R&D Activities & R&D Investment Per Capita)

Variable	External R&D activities				Variable	R&D investment per capita			
	Asia	Europe	North America	Others		Asia	Europe	North America	Others
External R&D activities	0.17(0.19)	-0.05(0.37)	0.79(0.31)**	1.17(0.64)*	R&D investment per capita	3.31(1.92)*	3.25(3.59)	2.72(2.78)	9.45(2.96)***
Log revenue	1.44(0.72)**	-0.04(1.29)	2.76(1.69)	1.61(2.87)	Log revenue	1.40(0.71)*	-0.06(1.25)	2.70(1.63)*	2.14(3.53)
Log revenue squared	-0.06(0.04)*	0.00(0.06)	-0.10(0.08)	-0.12(0.16)	Log revenue squared	-0.06(0.04)*	0.00(0.06)	-0.10(0.08)	-0.15(0.20)
Log number of employees	0.11(0.71)	1.00(1.43)	1.05(1.47)	6.06(4.69)	Log number of employees	0.23(0.71)	1.12(1.38)	1.08(1.46)	5.98(4.43)
Log number of employees squared	0.04(0.08)	-0.02(0.16)	-0.10(0.16)	-0.64(0.57)	Log number of employees squared	0.03(0.08)	-0.03(0.15)	-0.10(0.16)	-0.63(0.54)
High technology	-0.20(0.22)	-0.27(0.42)	0.02(0.43)	-0.25(0.81)	High technology	-0.24(0.21)	-0.28(0.41)	-0.16(0.42)	-0.44(0.79)
Medium technology	-0.76(0.26)***	-0.38(0.50)	-0.58(0.50)	-1.73(1.13)	Medium technology	-0.79(0.26)***	-0.39(0.50)	-0.68(0.49)	-1.84(1.13)
Low technology	-1.39(0.27)***	-1.65(0.61)***	-0.86(0.53)	-0.64(0.95)	Low technology	-1.39(0.27)***	-1.64(0.62)***	-0.85(0.51)*	-0.70(0.93)
Log business experience	0.03(0.14)	0.00(0.33)	0.27(0.31)	-0.73(0.62)	Log business experience	0.03(0.15)	0.00(0.33)	0.28(0.30)	-0.73(0.64)
Medium companies	0.33(0.49)	0.74(0.72)	1.84(1.28)	11.92(0.90)***	Medium companies	0.31(0.49)	0.71(0.71)	1.77(1.20)	10.43(0.93)***
Small companies	0.43(0.54)	0.49(0.88)	2.50(1.37)*	12.18(0.87)***	Small companies	0.42(0.54)	0.47(0.87)	2.45(1.29)*	10.67(0.84)***
Location in metropolitan area	0.01(0.17)	-0.31(0.33)	0.19(0.33)	-1.08(0.56)*	Location in metropolitan area	-0.00(0.17)	-0.32(0.34)	0.18(0.32)	-1.13(0.57)**
Tax support	0.86(0.21)***	0.93(0.47)**	0.69(0.42)	0.40(0.65)	Tax support	0.89(0.21)***	0.93(0.47)**	0.72(0.42)*	0.28(0.62)
Funding	0.35(0.22)	0.40(0.40)	-0.17(0.34)	-0.70(0.82)	Funding	0.34(0.22)	0.38(0.40)	-0.15(0.35)	-0.65(0.81)
Financial support	-0.18(0.25)	-0.57(0.46)	0.68(0.35)*	-0.31(0.78)	Financial support	-0.19(0.25)	-0.56(0.46)	0.69(0.36)*	-0.38(0.80)
Human resource support	0.13(0.26)	0.35(0.45)	1.12(0.48)**	0.21(0.63)	Human resource support	0.13(0.26)	0.36(0.45)	1.19(0.48)**	0.39(0.76)
Technical support	-0.45(0.25)*	-0.23(0.47)	-1.63(0.45)***	-1.97(1.25)	Technical support	-0.42(0.25)*	-0.26(0.47)	-1.57(0.45)***	-1.70(1.17)
Certification support	-0.57(0.25)**	-1.07(0.49)**	0.19(0.46)	-0.84(0.51)	Certification support	-0.59(0.25)**	-1.08(0.48)**	0.21(0.47)	-0.89(0.54)
Purchase support	0.53(0.28)*	0.73(0.50)	-0.00(0.46)	1.02(1.01)	Purchase support	0.56(0.29)**	0.75(0.50)	0.02(0.47)	1.07(0.95)
Constant	-10.04(3.03)***	-6.59(5.45)	-25.26(6.94)***	-30.12(18.28)*	Constant	-9.99(3.01)***	-6.67(5.37)	-24.82(6.73)***	-30.54(20.97)
Observations	1,137	1,137	1,137	1,137	Observations	1,137	1,137	1,137	1,137

Note: 1) ( ) is the standard error.
2) *, ** and *** mean that there is significance at the 1%, 5%, and 10% levels, respectively.

<Appendix 5> Results of Multinomial Logit Model Regression Analysis (R&D Intensity & Ratio of personnel dedicated to R&D)

Variable	R&D Intensity				Variable	Ratio of personnel dedicated to R&D			
	Asia	Europe	North America	Others		Asia	Europe	North America	Others
R&D Intensity	-0.0010(0.00)	-0.0305(0.02)	0.0005(0.01)	0.0007(0.00)	Ratio of personnel dedicated to R&D	0.0285(0.01)***	0.0264(0.01)***	0.0340(0.01)***	0.0127(0.02)
Log revenue	1.37(0.76)*	-0.57(1.62)	2.70(1.65)	2.12(4.53)	Log revenue	0.73(0.44)	-0.15(0.90)	-0.65(0.77)	2.42(3.33)
Log revenue squared	-0.06(0.04)	0.03(0.08)	-0.10(0.08)	-0.14(0.24)	Log revenue squared	-0.02(0.02)	0.02(0.04)	0.05(0.04)	-0.12(0.18)
Log number of employees	0.18(0.73)	1.32(1.62)	1.03(1.44)	5.57(3.99)	Log number of employees	0.31(0.46)	0.68(1.02)	1.86(0.84)**	1.73(2.28)
Log number of employees squared	0.03(0.09)	-0.05(0.17)	-0.10(0.15)	-0.60(0.49)	Log number of employees squared	-0.00(0.06)	-0.02(0.11)	-0.17(0.09)*	-0.18(0.26)
High technology	-0.24(0.21)	-0.28(0.41)	-0.15(0.42)	-0.44(0.78)	High technology	-0.03(0.16)	0.12(0.33)	0.03(0.32)	-0.13(0.67)
Medium technology	-0.78(0.26)***	-0.40(0.50)	-0.67(0.49)	-1.85(1.14)	Medium technology	-0.58(0.19)***	-0.28(0.39)	-0.25(0.38)	-1.06(0.78)
Low technology	-1.41(0.27)***	-1.71(0.62)***	-0.87(0.51)*	-0.74(0.93)	Low technology	-0.81(0.20)***	-0.43(0.40)	-0.38(0.39)	-0.92(0.87)
Log business experience	0.02(0.15)	-0.00(0.32)	0.28(0.30)	-0.73(0.63)	Log business experience	0.40(0.10)***	0.26(0.20)	0.59(0.20)***	-0.02(0.38)
Medium companies	0.33(0.49)	0.75(0.71)	1.78(1.21)	12.24(0.90)***	Medium companies	0.39(0.36)	0.78(0.60)	0.37(0.56)	12.31(0.80)***
Small companies	0.43(0.54)	0.47(0.87)	2.46(1.30)*	12.43(0.83)***	Small companies	0.60(0.38)	0.31(0.69)	0.27(0.64)	12.25(1.00)***
Location in metropolitan area	-0.01(0.17)	-0.35(0.34)	0.18(0.32)	-1.12(0.55)**	Location in metropolitan area	0.28(0.11)**	-0.06(0.23)	0.43(0.24)*	-0.77(0.47)
Tax support	0.87(0.21)***	0.96(0.47)**	0.71(0.42)*	0.30(0.63)	Tax support	0.82(0.15)***	0.99(0.31)***	0.85(0.29)***	1.07(0.54)*
Funding	0.36(0.22)*	0.42(0.40)	-0.14(0.35)	-0.59(0.80)	Funding	0.26(0.16)	0.14(0.35)	-0.06(0.29)	-0.44(0.74)
Financial support	-0.19(0.25)	-0.54(0.46)	0.69(0.36)*	-0.37 (0.81)	Financial support	-0.04(0.18)	0.16(0.40)	0.55(0.30)*	-0.56(0.76)
Human resource support	0.14(0.26)	0.34(0.45)	1.20(0.48)**	0.40(0.74)	Human resource support	-0.15(0.19)	-0.24(0.33)	0.67(0.36)*	0.18(0.63)
Technical support	-0.42(0.25)*	-0.27(0.47)	-1.57(0.45)***	-1.63(1.16)	Technical support	-0.32(0.19)*	0.23(0.37)	-0.72(0.36)**	-0.87(1.22)
Certification support	-0.59(0.25)**	-1.01(0.48)**	0.21(0.47)	-0.89(0.53)*	Certification support	-0.18(0.19)	-1.02(0.41)**	0.05(0.38)	-0.03(0.68)
Purchase support	0.54(0.28)*	0.69(0.50)	0.01(0.47)	1.00(0.99)	Purchase support	0.42(0.22)*	0.48(0.42)	-0.29(0.43)	-0.50(0.95)
Constant	-9.72(3.19)***	-4.22(6.51)	-24.75(6.84)***	-31.57(24.00)	Constant	-9.37(1.83)***	-7.31(3.59)**	-8.49(3.52)**	-31.13(15.55)**
Observations	1,137	1,137	1,137	1,137	Observations	2,876	2,876	2,876	2,876

Note: 1) ( ) is the standard error.
2) *, ** and *** mean that there is significance at the 1%, 5%, and 10% levels, respectively.