R&D and Firm Sizes in the IT Industry of Korea

1. Introduction

Telecommunications service and electrical power service, so far, have been regarded as natural monopoly to which economies of scale applies. For this reason, most governments have acknowledged the necessity of monopoly, and at the same time prepared a number of regulatory measures such as rate-of-return regulation, to counteract the inefficiencies of monopoly. Since, however, the theory of contestable market was developed by Baumol, W. J. et al. (1982). The new theory has been recently adopted as an approval of recommendations for a public policy in industries undergoing a transition to deregulation, particularly regulated transportation industries, telecommunications, or banks. In practice, the privatization of telecommunications business started in the mid-1980s in developed countries including the USA, UK and Japan. It initiated the gradual breakdown of monopoly system. Especially, UK abolished in 1991, after examining its duopoly system, the restrictive regulation that had given only BT and Mercury the rights to operate telecommunications services and granted CATV operators the license to provide telephone services. In February 1996, the USA Congress passed a new telecommunications law, virtually lifting barriers between broadcasting and telecommunications services and launching full-scale competition.

At this point, it is necessary to question what initiates the disintegration of the monopoly system in the information and telecommunications service market and drives the market into a competitive one. The answer seems to lie in the rapidly changing information and telecommunications technology, which is marching towards the multimedia era. A study on how the development of information and telecommunications technology affects the market structure and regulatory system, based on the cases of the USA and UK (Kim, 1996), shows that the structure of information and telecommunications service market changes from monopoly to competition due to technological progress.

There is a lot of technological region still undeveloped in the information and telecommunications industry. Since technology development in the market leads to the creation of more business opportunities than any other industry, dynamic process is expected to take place, accelerating competition. This fact gives us an intuition that small and medium-sized firms will make more efforts in technology development than large-sized ones in the information and telecommunications industry. If this proves to be correct, at least the information and telecommunications industry does not seem to be subject to the Schumpeter hypothesis.

The Schumpeterian views carry a wide range hypothesis concerning the importance of entrepreneur

as well as the scale of corporation in the evolution process.[1] This paper focuses on the analysis of the relationship between firm size and R&D. This paper aims primarily to verify by empirical study whether the Schumpeter hypothesis can be directly applied to the entire information and telecommunications industry of South Korea, including telecommunications equipment industry and services. The secondary objective is to provide an answer, based on the results of the analysis, to the question: which industry should be given priority if the government is going to support the information and telecommunications industry with limited financial resources?

This paper is structured as following. Chapter 2 examines the previous theoretical or experimental studies regarding the Schumpeter hypothesis. Chapter 3 discusses preparatory works required for the empirical analysis of the model employed in this study. Chapter 4 analyzes the effects of firm size on the amount of R&D activities. Chapter 5 summarizes the results of the analysis and suggests probable governmental policies regarding information and telecommunications technology in South Korea.

2. Review of previous studies

Schumpeter's(1942) classic discussion suggests that there were primarily qualitative differences between the R&D activities of small entrepreneurial firms and those of large modern corporations with formal R&D laboratories. Nonetheless, the empirical literature has interpreted Schumpeter's assertion that a large business entity has advantage in innovation.

With regards to the size of firms, Galbraith (1952) explicitly argued that large-sized firms confer advantages in innovation. Over the years, several justifications for this argument have been made. First, R&D activities require strong financial resources, and large-sized firms are more advantageous in this sense. Second, R&D investment is accompanied by high risks, and large-sized firms are in a better position to take such risks. Third, large and diversified firms can carry out more effective R&D relying on the scale economies and economies of scope in the R&D function. However, counter-arguments(Scherer and Ross, 1990) against the above assertions exist that efficiency in R&D is undermined because of the loss of managerial control or excessive bureaucratic control, as the size of firm grows larger.

Over several decades of empirical research on the relationship between firm size and R&D have spawned a number of robust empirical patterns. Notwithstanding the skepticism expressed by Schmookler (1959), early research based on National Science Foundation data from the 1950s and early 1960s established the positive relationship between R&D and firm size (Villard, 1958; Worley, 1961; Hamberg, 1964; Nelson et al. 1967). More recently, Bound et. al. (1984) and Cohen et. al. (1987) have noted a similar pattern while controlling for industry effects.

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[1] Recently, many papers addressing the issues have been published. For a recent reference, see Acs (1995).

The earliest studies, which used samples spanning multiple industries and included no controls for industry effects (Horowitz, 1962; Hamberg, 1964), concluded that R&D rose somewhat higher than the level proportionate to firm size. The omission of such industry effects is, however, likely to bias estimates of the effects of size on innovation (cf. Nelson et al. 1967; Baldwin and Scott, 1987). Although some of the studies conducted using samples spanning multiple industries and controlling for industry effects (e.g. Comanor, 1967; Meisel and Lin, 1983) found that R&D rose higher than the level proportionate to firm size. Uekusa (1982) and Scherer (1984) indicated that R&D activities grew faster than the speed of firm size growing up to a critical firm size, at which their growth began to slow down and eventually decelerate with increasing firm size. Their findings were given the profession's tentative consensus by the early 1980s. In the study of Bound et al. (1984) conducted using a larger and more comprehensive sample, R&D intensity falls slightly with size among the very smallest firms and rises somewhat with firm size among the largest firms.

Notwithstanding the various challenges in evaluating the R&D-firm size relationship, the consensus exists that either in the majority of industries or when controlling for industry effects in more aggregated samples, R&D rises proportionately with firm size among R&D performers (e.g. Baldwin and Scott, 1987; Scherer and Ross, 1990). This finding has been widely interpreted as indicating that, contrary to Schumpeter, large size offered no advantage in the conduct of R&D.

On the other hand, the industry-level analyses (Mansfield, 1964; Soete, 1979; Link, 1981; Scherer, 1965, 1984; Link, Seaks and Woodbery, 1988) suggested that there was the positive relationship between R&D and firm size among R&D performers except for few industries. For example, R&D was found to rise more than proportionately with size in chemicals (Mansfield, 1964; Scherer, 1965), less than proportionately in drugs (Mansfield, 1964; Grabowski, 1968), and both less than and greater than proportionately in a number of other industries (Soete, 1979). One weakness, however, of the industry-level studies is that due to the small sample-size for most individual industries, there is a statistical presumption in favor of the null hypothesis of proportionality (Cohen and Klepper, 1994).

The empirical studies on the R&D-firm size relationship, which have been carried out by recent years, can be largely divided into following two categories: the first is the comparative analysis of large and small and medium-sized firms, and the second is the analysis of the relationship between firm sizes and R&D activities within large-sized firms. For example, Gellman (1982) emphasized the role of small and medium-sized firms in R&D activities in his analysis recording of major technological innovations. These studies showed that small and medium-sized firms conducted R&D at the same level as or higher level than large-sized firms did. Uekusa (1982) and Scherer (1984) carried out studies on the case of large-sized firms with a high concentration of R&D activities. This study employs the first method to analyze the relationship between firm sizes and R&D activities.

Besides the above literature, there are some useful publications: Acs and Audretsch (1987) tested the hypothesis of which side of large firms and small firms has the relative innovative advantage is determined by market concentration, entry barriers, composition of firm size within the industry, and overall importance of innovation activity. They (1988) also presented a model suggesting that

innovative output be influenced by R&D and market. Katrak (1989) examined the effects of import of technology on the R&D activities of Indian enterprises. Audretsch and Vivarelli (1996) found that the spillovers from university research are apparently more important for small-firm innovation than for large-firm innovation in Italy.

The validity of Schumpeter hypothesis is not universal, but it depends on the nature of the industry. Without being accompanied by empirical analysis, intuitive deduction as to whether the size of a firm has positive or negative effects on its R&D activities seems inaccurate. The effects of firm size on R&D is examined in the Information & Telecommunications industry of South Korea in this paper.

3. Methodology of empirical analysis

A. Variables in R&D

This section analyzes the effects of firm sizes on R&D activities at the firm level, with regards to the information and telecommunications industry.[2] The R&D efforts of a firm can be measured in terms of R&D expense and manpower; and its performance, in terms of the number of patents, the growth rate of productivity, and the sales amount of new products. In this study, R&D efforts is measured using statistical data for R&D expense and manpower; and R&D performance is measured using statistical data only for growth in sales amount, due to the limited availability of information.

One cautionary consideration to make before making analysis using these variables is the fact that the Korean information and telecommunications industry has been an active importer of foreign technologies, and whether R&D expense may accurately reflect a firm's attitude towards R&D activities in this case. If R&D expense and foreign technology import are having a confronting relationship, the analysis of the former only produces a result of no economic implication. However, in Korea, the introduction of foreign technology has been accompanied by R&D efforts for

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[2] The information and telecommunications (I&T) industry is distributed over the secondary and third industries, and continues to expand its domain. For this reason, there is no standardized classification system even in developed countries. A number of related governmental and private organizations had published independently, often inconsistent, statistical data in Korea. In late 1994, the Telecommunications Technology Association (TTA), an umbrella organization under the Ministry of Information and Communications of Korea, prepared a standardized classification system for the IT industry, in order to prevent confusion and provide consistency in data analysis. This system classifies the industry into four categories: IT services, IT equipment, software and IT support. This paper is based on this classification system, but the support sector is included in the service sector, for the number of its samples was too small and by nature it is close to the latter.

application of the imported technology, and their relationship can be regarded as rather complementary. It is not unreasonable to consider that R&D expenses reflect a firm's attitude towards R&D activities, with regards to the information and telecommunications sector, and thus technology import will not be separately considered in this study. The variables used in this study, especially R&D expense, do have the above-mentioned weaknesses and conditions, but even these may be permitted in analysis if viable deductions are achievable despite these limitations.

B. Experimental model and variables

This study uses following equations:

$$RD = a_0 + a_1 FS \qquad (1)$$

$$\log (RD) = \alpha + \eta \log (FS) \qquad (2)$$

where *RD* denotes R&D expense or R&D manpower; *FS*, sales amount or the number of employees; a_0, a_1, α, and η, presumed parameters.

The above equations (1) and (2) are used to determine the relationship between R&D efforts and firm sizes. The relationship is examined in duplicate using different variables. First, sales amount is used as explanatory variable, and R&D expense, as response variable. Next, the number of employees is used as explanatory variable, and R&D manpower, as response variable. The regression coefficient η in Equation (2) can be interpreted as the elasticity of R&D variables with respect to firm size, representing proportional testing between R&D efforts and firm sizes. Equation (2) can be understood in the following way. If $\eta>1$, R&D efforts increase at a faster rate than increase in firm sizes; if $\eta<1$, R&D efforts increase at a slower rate than increase in firm sizes; and If $\eta=1$, R&D efforts increase in proportion to increase in firm sizes.

In general, R&D includes both R&D efforts and performance. In many cases, R&D performance is assumed to increase in proportion or more than in proportion to R&D efforts, and there are a number of analytic studies supporting this relationship. Therefore it is a general practice to make direct use of the analysis of R&D efforts in the estimation of R&D performance.

However, the above assumption cannot be regarded to be accurate in all cases. The mutual relationship between firm sizes, R&D efforts and performance is composed of the relationship between firm sizes (*FS*) and R&D efforts (*RD*), and the relationship between R&D efforts and R&D performance (*OT*). If we denote the elasticity R&D performance on R&D efforts by γ, the relationship between the three can be expressed as follows:

$$\log (OT) = \beta + \gamma \log (RD) = \beta + \gamma \log \alpha + \eta \cdot \gamma \log (FS) \quad (3)$$

where α, β, γ and η are integers.

Similar interpretation for η in equation (2) can be made for the parameters γ and $\eta \cdot \gamma$ in equation (3). These relationships suggest that the relationship between firm sizes and R&D efforts do not directly correspond to that between firm sizes and R&D performance, for the latter relationship depends not only on η, but also γ. If the conversion relationship between R&D efforts and its performance is a linearly homogeneous function, where $\gamma=1$, then the two relationships are directly corresponding to each other. Otherwise, it cannot be considered so. Therefore, it is necessary to study the relationship between R&D efforts and its performance.

In January 1996, the Ministry of Information and Communications of Korea conducted a questionnaire survey on effective assistance to informatization promotion fund, which was sent to those firms entitled to the fund. About 130 firms, 38% of all firms surveyed, responded to the questionnaire. Their answers were analyzed to study the effects of firm sizes on R&D activities.

Respondents were asked to write down the amount of capital, sales revenue, patents and the number of employees annually from 1991 to 1995, but many did not list them for 1991, 1992 and 1995 and, in particular, few wrote down patents. This is partly attributable to the fact that many were established after 1993, and in case of many firms, accounting for the fiscal year of 1995 was not completed yet as of January 1996. With regards to R&D manpower and R&D expenses, most respondents gave only 1994 figures. Because of these statistical reasons, this study used the 1994 statistics of R&D expense, manpower, sales revenue and number of employees, in order to analyze relationships between firm sizes and R&D efforts. However, the 1993 data were also used partly, because the difference between 1994 and 1993 sales amounts was used as the parameter for market performance. In this study, 94 samples were selected for analysis of the relationship between sales amount and R&D expense; 81 samples, for the relationship between the number of employees and R&D manpower; and 79 samples, for the relationship between R&D efforts and performance.

4. An analysis of the results

A. Firm size and R&D efforts

In this section, the relationship between R&D expense and sales amount is studied, on the basis of the result of the regressive analysis which was carried out in conformity with Equations (1) and (2). As shown in Table 1, the elasticity value of the R&D expense over sales amount is 0.59, at about 1% significance level. As it is less than 1, the R&D spending of the overall IT industry grows at a slower

rate than increase in sales revenue.

TABLE I

Relationship between sales revenue and R&D spending (1994)

Subordinate variable	Constant	FS	Log FS	R^2
RD	-2.85	4.78		0.84
	(-0.02)	(21.99*)		[483.64*]
Log RD	3.62		0.59	0.52
	(12.92*)		(9.95*)	[98.90*]

[a] The number in ( ) denotes the t-value; that in [ ], F-value; and R^2, coefficient of determinant.

[b] The unit of sales revenue is 100 million won, and R&D spending, 1 million won.

* indicates the significance level at 1% level.

A lot of previous empirical studies and analyses have increasingly pointed out that different industries exhibit different relationships between firm sizes and R&D efforts. The above is the analysis of the overall information and telecommunications industry. However, as information and telecommunications firms extend to the service, equipment and software industries as well, it is not possible to avoid criticism that the characteristics of different industries were not taken into consideration in the analysis. In this study, therefore, we classify firms to be analyzed into service, equipment, and software sectors, for each of which relationships between firm sizes and R&D efforts are examined.

TABLE II shows the ratio of R&D spending to sales amount (denoted as R&D ratio hereafter) per capital size as of late 1994, based on the standard classification system issued by the Ministry of Information and Communications of Korea. It indicates that large-sized firms tend to have smaller R&D ratios, over the entire information and telecommunications industry. Therefore, it is not accurate to conclude that R&D activities are in proportion to firm sizes, with regards to the information and telecommunications industry.

Even when we divide the information and telecommunications industry into service, equipment and software sectors, and examine their R&D ratios, respectively, it shows that R&D ratios decrease with increasing firm size. By sector, R&D activities are concentrated mostly on software, then followed by equipment and service areas. It reflects the general concept that more R&D efforts are made in the manufacturing sector than in the service sector.

The relationship between the number of employees and R&D manpower also shows that R&D

manpower grows at a slower rate than increase in the number of employees (See Appendix). On the other hand, the ratio of R&D manpower to the number of employees per capital size indicates that firms with a larger number of employees have relatively smaller ratios of R&D manpower than small firms. These results correspond with those of the relationship between sales amount and R&D expenses.

In explaining the relationship between firm sizes and R&D efforts, the ratio of R&D spending to sales amount appears to be of more significance than the relationship between the number of employees and R&D manpower. The former has an R^2 value of 0.38 and a logarithmic value of 0.26, while the letter has 0.84 and 0.52, respectively.

It should be, of course, taken into consideration that the number of small and medium-sized firms conducting R&D activities is relatively smaller than that of large-sized firms. However, so far as those who carry out R&D are concerned, small and medium-sized firms are more active in R&D, in terms of R&D ratios, than large-sized firms.

B. R&D efforts and its performance

The inter-relationship between firm sizes (*FS*), R&D efforts (*RD*) and R&D performance (*OT*) is examined in this section, on the basis of the model suggested in Chapter 3. The analysis is made in two stages: first, relationship between firm sizes and R&D efforts, and next, relationship between R&D efforts and its performance.[3]

TABLE II

Ratios of R&D spending over sales amount in each sector (unit: %)

Capital	Less than 1 Billion won	Less than 10 Billion won	More than 10 Billion won	Overall average
IT service	10.10(177.09)	9.04(3015.50)	6.81(8964.67)	9.16(2272.44)
IT equipment	20.99(379.00)	10.42(1004.29)	2.18(7935.15)	11.30(1521.63)
Software	17.76(431.29)	15.10(1723.25)	7.09(4625.50)	15.61 (883.17)
Total	15.81(361.75)	11.38(1307.64)	4.09(7614.17)	12.15(1466.88)

Note: The numbers in ( ) indicate the average R&D spending per capital amount, in units of 1 million won.

[3] Here the relationship between R&D efforts and performance is analyzed, centering on the ratio of R&D spending to sales revenue, which is regarded as a better, more meaningful measure for the relationship between firm size and R&D efforts.

The first stage has already been carried out in Chapter 3, by using two independent combinations of R&D spending and sales revenue, and R&D manpower and the number of employees as parameters for R&D efforts and firm sizes, respectively. The result of the analysis is presented as log RD= 3.62 + 0.59 log FS (η=0.59), as shown in Table 1. It shows that R&D efforts increase at a slower rate than increase in firm sizes.

The second stage is to examine the relationship between R&D efforts and its performance. The following equation describes the effects of R&D efforts (R&D spending) on R&D performance (increase in sales amount). The t-value in the brackets and R^2-value are considered to be significant at 1% level.

$$\log OT = -1.98 + 0.83 \log RD, \quad R^2 = 0.48 \; [77.18^*]$$
$$(-3.24^*) \quad (8.79^*)$$

In this model, the value of γ is 0.83, which indicates that R&D performance is less than proportional to R&D efforts. In other words, R&D efforts do not necessarily lead to its performance. However, interpreting the analysis results, we should take into consideration that long-term R&D investment takes time to be realized.

Multiplying the values of η and γ obtained from above, to measure effects of firm sizes on R&D performance, results in $\eta \cdot \gamma = 0.49$. Its economic rationale for being less than 1 indicates that R&D performance increases at a slower rate than increase in firm sizes.

FIGURE I

FIGURE I shows the relationship between firm sizes, R&D efforts and its performance. For example, firm A of a size FS_A is compared with firm B of twice the size (FS_B) in Figure 1. The R&D efforts of firm B, RD_B, is less than twice that of firm A, RD_A, which shows that R&D efforts do not grow at the same rate as firm sizes. On the other hand, the gap in R&D performance increases at a far slower rate than the gap in R&D effort increases. The economic rationale for these facts is that the ratio of R&D efforts to firm sizes decreases with increasing firm size, and that the ratio of R&D performance to its efforts also decreases acceleratively with increasing R&D efforts. In other words, smaller firms conduct relatively more active and more effective R&D activities.[4]

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[4]) The relationships between these parameters can be seen more clearly with numerical examples. When there are two firms of sizes FS_A and FS_B, where FS_A=1 and FS_B=2, R&D efforts by firm B increase about 1.5 times RD_A=1 and RD_B=1.51), and R&D performance, only about 1.4 times (OT_A=1 and OT_B=1.41).

5. Conclusions

In this paper, the effect of firm sizes on R&D efforts in the information and telecommunication industry of Korea was analyzed, which can be summarized as follows:

First, regarding the relationship between firm sizes and R&D efforts, (1) a firm with larger sales revenue does invest more in R&D than a firm with smaller sales revenue, but the ratio of R&D spending to sales amount decreases with increasing sales amount, and (2) a firm which employs more has larger R&D workforce, but the ratio of R&D manpower to the number of employees decreases as the number of employees increases. These two relationships lead to a deductive conclusion that in the information and telecommunication industry, larger firms are relatively less active in R&D.

TABLE III shows the relations of firm size and R&D in the small and medium-sized firms and large firms in terms of the relation of sales revenue to R&D spending. Average sales of standard large firms and small and medium-sized firms are 257,775 million won and 7,081 million, respectively, which shows the sales revenue of large firms is about 36 times larger than small and medium-sized firms. R&D spending of large firms and small and medium-sized firms are 7,614 million won and 816 million, respectively, which shows 9 times of the difference. This suggests that R&D spending of small and medium-sized firms is smaller than large firms in terms of absolute amount, but the ratio of R&D spending over sales revenue of the former is much higher than the latter. According to the TABLE III, the ratio of R&D spending over sales revenue of small and medium-sized firms is 12.51% and that of large firms is 4.09%, which shows the ratio of the former is three times larger than the latter. Average number of employees of large firms and small and medium-sized firms are 724 and 79, respectively, which shows the nine times of difference between the two. On the other hand, average number of R&D manpower of large firms and small and medium-sized firms are 72 and 15 respectively, which shows the five times of difference between the former and the latter. This suggests that small and medium-sized firms have smaller R&D manpower than large firms do, but their ratio of R&D manpower to total employees is much higher than large firms. Small and medium-sized firms' average ratio of R&D manpower to the number of employees is 18.12%, while the ratio of large firms is only 9.59%.

TABLE III

Sales revenue, R&D spending, and Ratios of R&D spending over sales amount

	Sales revenue (million won)		R&D spending (million won)		Ratios of R&D spending over sales revenue (%)	
	Small and medium-sized firms	Large firms	Small and medium-sized firms	Large firms	Small and medium-sized firms	Large firms
IT Service	12288	131640	1123	8965	9.14	6.81
Information and telecommunications Equipment	6256	363998	734	7935	11.74	2.18
Software	5944	65240	883	4626	15.76	7.09
Total	7081	257775	817	7614	12.51	4.09

Note: A firm with equity capital higher than 10 billion won is included in the large firm group, and a firm with equity capital lower than 10 billion won is classified into the small and medium-sized firm group.

Second, the software sector has the highest ratios of R&D spending to sales amount, and R &D manpower to the number of employees among the IT industry. In other words, a lot of R&D activities are concentrated on the software sector (See TABLES II and III).

Finally, the mutual relationships among firm sizes, R&D efforts and its performance are as follows: (1) As R&D performance increases at a slower rate than R&D efforts, it is not accurate to assume that R&D efforts necessarily lead to successful performance. (2) R&D performance increases less than in proportion to increasing firm size.

These eventually lead to the conclusion that the Schumpeter hypothesis, that large-sized firms conduct R&D activities at a higher ratio than small and medium-sized firms, does not hold valid for the information and telecommunication industry of Korea. In addition, it suggests that more governmental support be given to those small and medium-sized firms, which exert higher ratios of R&D efforts to firm sizes, and achieve relatively more effective performance. More support is also given, in particular, to the software sector on which most R&D efforts are concentrated.

Appendix

In the appendix, the relationship between the number of employees and R&D manpower is studied, on the basis of the result of the regressive analysis conducted in conformity with the equations (1) and (2) as presented in Chapter 3. As shown in Table A-1, the elasticity value of R&D manpower over the number of employees is 0.46, and significant at 1% level. Since this value is less than 1, it indicates that R&D manpower grows at a slower rate than increase in the number of employees.

TABLE A-I

Relationship between the number of employees and R&D manpower (1994)

Subordinate variable	Constant	FS	Log FS	R^2
RD	-1.81	0.09		0.38
	(0.26)	(6.91*)		[47.70*]
Log RD	0.05		0.46	0.26
	(0.12)		(5.25*)	[27.52*]

Note: The same as in Table 1.

Table A-2 shows the ratio of R&D manpower to the number of employees per capital size, as of late 1994. As shown in this table, firms with a larger number of employees have relatively smaller ratios of R&D manpower than small firms. This trend is also apparent when we divide the IT industry into smaller sectors and examine each one separately. One interesting fact is that R&D efforts are concentrated on the software sector, not only in terms of sales amount but also in terms of manpower.

TABLE A-II

The ratio of R&D manpower to the number of employees(unit: %)

Capital	Less than 1 billion won	Less than 10 billion won	More than 10 billion won	Overall Average
IT service	21.94(5.89)	21.80(45.00)	5.01(39.33)	18.72(21.94)
IT equipment	17.24(5.60)	14.18(16.14)	12.58(99.71)	14.91(25.84)
Software	24.97(9.33)	21.47(26.67)	5.23(24.00)	21.17(12.87)
Total	20.97(7.26)	17.05(21.21)	9.59(72.00)	17.36(21.50)

Note: The number in ( ) denotes the average R&D manpower in each capital category.

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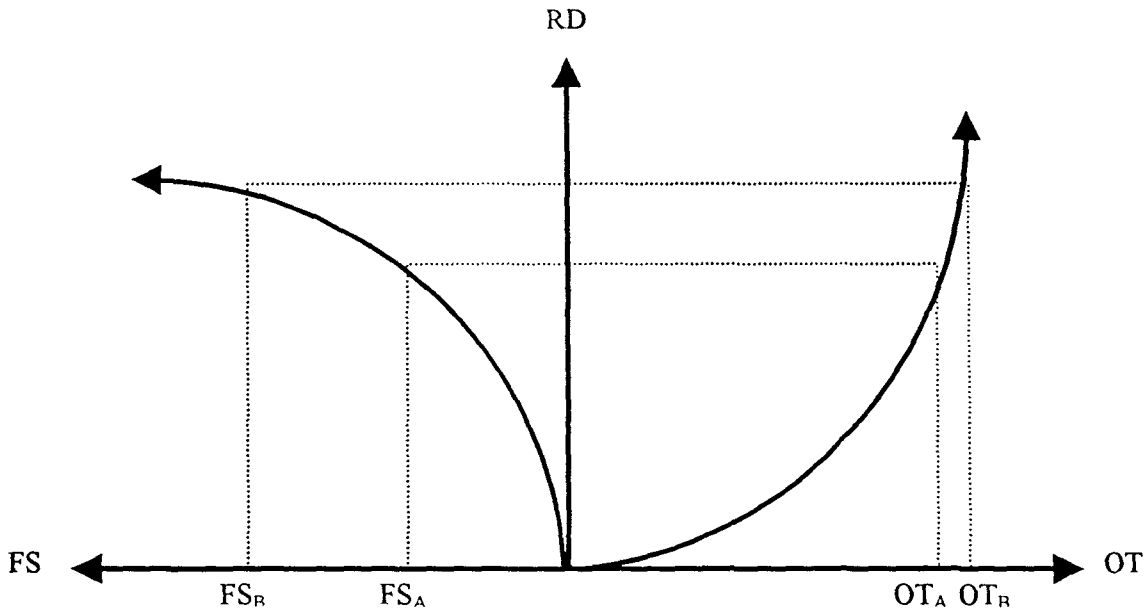

FIGURE I. Relationships between firm sizes, R&D efforts and its performance in the IT industry.