한국기업의 투자행태 분석
: 이론적 배경과 실증적 근거

THEORETICAL BACKGROUND AND EMPIRICAL EVIDENCE
FOR R&D AND ADVERTISING INVESTMENTS IN KOREA

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Theoretical Background and Empirical Evidence For R&D and Advertising Investments in Korea

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전통적인 산업조직이론에서 널리 사용되는 시장구조-행동-성과 분석 도구(The SCP Paradigm)는 시장성과가 가격정책, 기술개발투자(R&D), 광고투자, 생산설비 변경 등 시장행동의 함수라는 암묵적 가정에 근거한다. 최근 시장행동 중에서 기업의 관심이 크게 높아진 R&D 및 광고투자가 시장성과에 미치는 영향이 크게 부각되었으며, 시장성과를 구성하는 주요요인으로 주목받고 있다. R&D 및 광고투자의 성격과 행태, 그리고 시장성과에 미치는 영향이 상호 유사함에도 불구하고 두가지 변수를 동시에 다룬 연구는 매우 드물다. 몇 안되는 연구들도 기업의 행태를 실증적으로 설명하는 데 치중함으로써 이론적 근거를 소홀히 하는 경향을 보이고 있다. 즉, 논리의 전개상 이론적인 근거를 바탕으로 수리모형이 먼저 제시된 후에야 이를 검증하는 방법으로 통계모형을 사용하는 것이 옳을 것이다.

이 논문은 기존의 SCP 분석방법을 사용하여 기업이 한정된 재원을 어떤 원칙아래 R&D 및 광고에 분산투자하는 가를 설명하기 위해 수리모형을 설정한 후, 정태와 동학, 확실성과 불확실성, 단발성과 균등투자전략의 개념을 도입하여 다양한 분석을 시도하였다. 또 R&D 및 광고투자 함수를 이론적 근거에 의해 도입하되, 각 모형에 균형이 존재하는가를 검증하였다.

수리모형을 이용해 분석한 결과 (1) 기업의 투자는 R&D 및 광고투자간에 한계원리(Marginal Principle)가 지켜지도록 분배할 때에 효율적임이 판명되었고, (2) 동학모형이 정학모형을 포함하는 일반모형의 성격을 가지고 있었으며, (3) 투자는 확실성이 높을수록, 분산시킬수록 투자효과가 큰 것으로 나타났다.

한국을 대상으로 한 실증적 모형추정은 앞의 수리모형 및 그 결과에 근거를 두었으며, 한국기업에 적절한 R&D 및 광고투자함수를 추정한 뒤 이를 이용해 업종, 기업규모, 상품유형별로 적합한 모델(Fixed Effects Model)을 결정하고, 각각에 해당하는 통계모형을 구축하였다. 이 결과 (1) 업종 및 기업규모별로 그룹간에 유의한 특성이 발견되었으며, (2) R&D 및 광고투자는 기업의 시장성과를 설명하는 중요한 변수이나, (3) R&D투자의 경우는 광고에 비해 불확실성이 존재하는 것으로 나타났고, (4)수리모형에서 도출된 한계원리가 통계모형에서도 유효한 것으로 드러났다.

Section I : Introduction

It is widely recognized that R&D and advertising investments have impacts on markets, directly and indirectly. Firms, in fact, invest a considerable portion of their resources in R&D and advertising. Investments in R&D and advertising are on the rise as the sizes of Korean firms and economy are getting bigger.[1] Few firms invest only in either advertising or R&D.

Interestingly much attention had not been paid to the relationship between R&D and advertising until the early eighties. Consequently, despite having similar properties and desired goals there are few studies on how R&D and advertising are related and how they jointly affect the firms' performance.[2] Early studies have concentrated on separately investigating the optimal R&D and advertising levels. Rasmussen(1952) demonstrated the optimal advertising level of a firm in a static model, and Schmalensee(1972) extended this analysis to dynamic model in an oligopolistic market. Needham(1975) showed that the optimal R&D level of a firm in a static model is related to the elasticity of demand with respect to R&D.

R&D and advertising achieve their goals, increasing barriers to entry and revenue, by reducing cost and providing information to customers respectively.[3] When it comes to the probability of return of investments, R&D is riskier than advertising. In terms of elapsed time until the first return, advertising has advantage over R&D. Among numerous empirical studies suggesting that R&D and advertising influence the firms' performance[4], Strickland and Weiss(1976), Comanor and Wilson(1967), and Schmalensee(1972) are clearly outstanding.

This paper examines the firm's investment behavior on R&D and advertising and their effects on market performances. The introduction is followed by section II which carries a brief literature survey. In section III, a mathematical model is constructed and applied. Section IV deals with statistical models, based on the implications from the mathematical model, so that the facts found in the mathematical model are estimated and tested. The results of the mathematical and statistical models are summarized in section V.

I.1 Revaluation of R&D and advertising

Recent studies show that R&D and advertising have not only indirect (strategic) effect, but also direct effect on market performances, sharing strategic properties of

1) Ekelund and Saurman(1988) shows that advertising expenditure had grown tremendously both in developed and developing during the period of 1976-1981: United States: 82%, United Kingdom: 167%, Japan: 127%, Korea: 138%, Taiwan: 209%, Mexico: 80%.

2) For the detail, refer to Lee(1994).

3) For example, Lach and Schankerman(1989) empirically explores the dynamic interactions among R&D, capital investment, and the stock market performances. Using a framework of dynamic factor analysis, this paper concludes that R&D causes investment, but that investment does not cause R&D : unidirectional effect. A combined increase of $100 in both R&D and investment is accompanied by a rise in the stock market value of the firm(net of these costs) of $18.

4) According to Bain(1956), there are two main sources of barriers to entry:
(1) Special advantage such as low financial cost, and (2) Economies of large scale such as economies of scale, advantages of being first, diversification advantages, and advantages of big business.

investment.

First, there are many studies which examine the entry barrier creating effect as well as the scale economies of R&D and advertising. These effects can be considered as strategic ones because they indirectly affect the performances. Second, a few studies discuss the mechanism of the SCP (structure - conduct - performance) paradigm and most of them suggest the validity of the approach. Despite some criticism for its simplicity, the SCP approach is still mainly used in most industrial organization papers, and persuasive in explaining the interrelationships between the market structure and firms' conduct, and between firms' conduct and market performances. Finally, there are several studies which provide the economic evidence on the effects of advertising, so that pessimistic opinion that advertising has nothing to with any economic effects is abated.

I.2 Investment Risk and Method of allocation fund

The definition of investments in R&D and advertising, in terms of a degree of success, is significant so that the whole framework for any model in discussion is greatly affected. The possible cases, in terms of changes in market share, are one of the followings: (1) winner takes all (2) no effects at all, and (3) some case between (1) and (2). About the 'winner takes all' situation by R&D, Delbono and Denicolo(1991) is very pessimistic by saying that the assumption of 'winner takes all' may be inappropriate in case of cost reducing innovation, when firms are Cournot type of players in the product market. Their opinion suggests that the prize of winners depends on the number of firms. In other words, losers may still reap positive profits in the post-innovation equilibrium. Stewart(1983) also discarded this assumption and introduced a concept of share parameter, which indicates how the prize is split between the winner and losers.[5] Consequently, this paper also drops the case of 'winner takes all' and instead assumes throughout this paper the market in which both winners and losers still are in the same market after successful R&D and advertising.

The other assumption is about the method of allocating available funds over time. Out of many possible ways of spending, two possibilities are under consideration: (1) spending all the available money at the first time period(one-shot spending)(Loury, 1979), and (2) spending equal amount of money at each period(equal allocation of fund)(Lee and Wilde, 1980).

To avoid this possibility of having changeable results at the mercy of choosing spending method, both methods of one-shot spending and equal allocation of fund are adopted and compared to each other later for the mathematical models in section III.

Section II : R&D and Advertising

II.1 R&D

Until late 1970s, it had not been recognized that R&D have direct and significant relationship with market performances: Bisio and Gastwirt(1979). Later studies like

5) Stewart(1983) introduced a share parameter, σ, in his paper in which the winner gets a fraction , σ, of the prize and the losers which get $\frac{1-\sigma}{n-1}$ where n is the number of firms in the industry.

Bergen(1983) and Bergen and Miyajima(1986) provide the empirical evidence on the value of R&D to firms and thus the relationship is newly recognized. Also Vernon and Nourse(1973), Strickland and Weiss(1976), Mueller(1986), and Nakao(1993).[6] R&D affects markets in two ways. Firstly, R&D investment leads to cost reducing innovations, and incurs increase in a firm's revenue and market share. The other factor pertains to the elation of R&D to barriers to entry. In this case, R&D investment is a strategic variable to allow incumbents to maintain their own stable market share by deterring the potential entrants.

In order for the level of a firm's R&D expenditure to be at a profit maximizing level, Needham(1975) shows that the effect of a change in the level of R&D expenditure on the firm's total revenue and total cost must be equal. This condition is called as marginal principle. The optimal ratio of a firm's R&D expenditure to sales, or R&D intensity as the ratio will henceforth be termed, will be larger the smaller the price-elasticity of demand for the firm's product.[7]

The methods of measuring the value of R&D which in most cases determine the outcomes of models can be classified into three categories: (1) patents : absolute number and ratio of patents to sales, capital or R&D expenditures, (2) stock market response : stock price, PER(price earning ratio), and etc., (3) market performances : sales and profit(before / after tax). The number of patents is commonly used as a proxy for the return from R&D: Scherer(1965). The patent as a variable has two serious problems. One is that the number of patents are very changeable by dividing a possible patent into several ones. The other one is that a great deal of patents are never exploited commercially. The variables from the stock market is easy to obtain, but whether the stock market movements fully reflect the firms performances is questionable. The market performance variables which have been widely used are profit as in Bergen and Miyajima(1986) and Lee(1986), Thomas(1989) and sales as in Thomas and Nguyen(1987), and productivity as in Bergen, Miyajima, and McLaughlin(1988). Again, these three variables can be divided into many specific variables to meet the research goals: by the price, tax and other factors.

The proposition that there exists a continuous positive relationship between firm size and R&D has been controversy since the early works like Schumpeter(1942) suggested the existence of the relationship. Summarizing Nelson(1967) and Pavitt(1987) in favor of the Schumpeter gives two reasons for the positive relationship: (1) capital market imperfectiveness confers an advantage on large firms since size is correlated with availability and stability of internally-generated fund, and (2) there is economies of scale in R&D. In the contrary, Horowitz(1962) and Mansfield(1964) oppose to the existence of the relationship, based on the poor and little empirical evidence.

It is worth noting the evolution of Scherer's research on this relationship. In his early paper, Scherer(1965) concludes that inventive output, measured by patents issued, increases less than proportionately with firm sale. Similarly, in a 1967 study of the relationship between firm size and R&D input, Comanor concludes that while there are few instances where the larger firms in an industry account for a larger proportion of industry R&D input than their share of industry size, in many cases the R&D-sales ratios of smaller firms in an industry, which are called R&D intensities, are larger than those of larger firms. Later based on the US data, Scherer(1984) asserts with new findings different from his early studies, saying that R&D intensity first falls and then rises with firm size. Consistent with Scherer(1984), Pavitt(1983) shows that very large firms are found to have the highest

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6) For example, Vernon and Nourse(1973), using a sample of large US firms, found that industry R&D intensities were strongly correlated with firm profitability than the firms' own intensities.

7) Section III carries the explanation on the optimal ratio in detail.

R&D intensity. Similar results in case of French firms are reported by Cremer and Sirbu(1978).

Despite many papers asserting the stylized relationship between firm size and R&D, the most notable feature of these empirical research on the relationship is its inconclusiveness: Cohen and Levin(1989). Acs and Audretsch(1987) and Dorfman(1987) answer to the long debate by proving that the relationship becomes easily changeable by industry condition, market structure and countries. For more information on the relationship R&D and market structure, refer to Lee(1994).

II.2 Advertising

By providing some information, at least that particular products exist, advertising extends to an effective scope of consumer choice and widens the range of choice. This presumed effect of advertising depends on the type of information provided,[8] and particularly on its influence on consumers' knowledge of relative product quality. Further study is done by Laband(1989), specifying advertising effects which can be more effective by selecting the means of media, for example, newspaper or TV, and which are different by the type of a firm, retailer or manufacturer.

On the informational role of advertising, Nelson(1974) has consistent result with the case study by Laband(1989).[9] The psychological analyses accept the limited effects of advertising, based on which the functional type is selected in section II. One of those is Hilke and Nelson(1984) which suggests that psychology research on information overload is consistent with the view that additional advertising may disrupt all firms' ability to communicate through advertising.

The relationship between advertising and demand can be summarized in two facts. The first is that advertising changes consumers' taste and creates values in the minds of consumers. Simply by advertising a product, a firm can either create a demand for the product or increasing the existing demand, resulting in the ability to change higher prices and to increase profitability(Comanor and Wilson, 1967). Advertising, secondly, creates consumer loyalty to the particular brand that is advertised, as opposed to other brands of the same general class of products. Over time, loyalty to the brand becomes stronger and stronger, so strong that other firms facing entry undergo troublesome disadvantage (Ekelund and Saurman, 1988).

Cubbin(1981) clearly summarizes a firm's behavior underlying entry barrier effects. He tries to give one explicit account of how advertising may act as an entry barrier and concludes that it is reasonable to suppose that advertising is responsible for some barrier effects in some industries. Wiggins and Lane(1983) shows how barriers, in type of product quality, can be generated by advertising.[10] Imperfect information generates risk which will

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8) According to Laband(1989), the range of information which can be conveyed from firms to potential customers is summarized as follows; product price, degree of product quality, seller location and telephone number, the availability of factory or dealer - sponsored financing, the rate at financing is offered, acceptance of charge cards and local checks as a payment mechanism, available selection, hours/dates of operation and a sale, peripheral service offered, size of seller or firm, and factory or dealer - backed guarantee on the product /service offered.

9) In the sample of Baltimore Sun advertising used in Laband(1989), fully 99.5% of all the advertising placed contained at least one of the informational characteristics with a standard error of 0.069 and the mean advertising contained 3.3 specific information with a standard error of 1.665. These results are consistent with Pollay's(1985) results for magazine advertising.

affect the decisions of risk-averse consumers(Kihlstrom and Riordan(1984) and Ornstein and Lustgarten(1978)). Many other papers favor the entry barrier creating effect of advertising. For example, Brown(1978) concludes that barriers to entry due to advertising do exist and are substantial(also in Mueller(1978), Kessides(1986), Rizzo and Zeckhauser(1990) and Mueller and Rogers(1984)),

Advertising is also considered as a strategic variable. To figure out this property, Cubbin and Domberger(1988) tries to test the proposition that post-entry advertising behavior may differ from pre-entry behavior, thus effectively establishing whether there is major evidence of predation, and in examining the conditions under which this occurs.

Dixit(1979) specifically shows that a firm's capacity can be used a strategic variable. He asserts that this more flexible notion of capacity of R&D or advertising can be interpreted in terms of other types of investment such as dealer networks and advertising, and this provides a basis for arguments that such expenditures can be used by an established firm in its efforts to deter entry.

Whether a simultaneous equation or a single equation system should be used is related with the hypothesis of constant advertising intensity. Inspired by Dorfman and Steiner(1954), Lambin(1976) finds that no systematic simultaneous relationship is observed between advertising and sales.[11]

II.3 Desirable approach to R&D and advertising in Korea

Most studies dealing with R&D and advertising in Korea are similar to each other in two ways: (1) they are centered on the SCP scheme, and (2) they are primarily empirical. The reason for the first characteristic noted above is that Korea still has a fast growing economy. Thus the traditional paradigm for analyzing an economy can be effective, because the effects of structure on conduct and the effects of conduct on performance are rarely irreversible. Even from the point of firms' view, they concentrate on market - oriented conducts to improve market performances rather than change the market structure which have been mainly affected by the government. Another reason comes from the growing potentials of domestic demand. Korean firms try to capture more share of the potential demand rather than to affect the market structure directly. Both R&D and advertising in many studies have been shown to explain well firms' performances: Kimenyi, Lee and Shughart(1990), Lee(1986), and Chang and Choi(1988),

It is quite recently that some industrial organization economists try to analyze the effects of R&D and advertising in the same framework. Hergert(1987) notes that there are five strategy variables affecting performances: advertising, R&D, capital intensity, ratio of total asset to sale and market share. Hergert also shows that advertising, R&D and concentration ratio are significant in explaining the return on sales. He also shows that the most common bases for this grouping lie in R&D and advertising.[12]

On the relationship between R&D and advertising, Morck and Yeung(1991)[13] find

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10) They incorporate risk into the model by assuming that consumers are concerned not only with expected product quality, but also with the amount of variation that exists across the qualities available. The factor that causes consumers to purchase advertised products is the lower variation in product quality in the advertised array.

11) For further discussion, refer to Lee(1994)

12) He argues that not only can group effects be shown to exist but that heir emergence can be linked to specific market characteristics. This implies the possibility that group effects can be found in other markets, for example foreign markets.

weak evidence that the absence of R&D or advertising may reduce firm value. Later, Nakao(1993) which deals with 31 Japanese firms consolidates Morck and Yeung's(1991) finding by asserting that R&D and advertising are not substitutes, but complements: moreover an increase in one results in another increase in the other. He also finds a positive effects of R&D and advertising on market performances. The same effects of R&D and advertising on market performances are consistently found in Korean firms: Kimenyi, Lee and Shughart(1990).

From the discussions above, some empirical grounds for the existence of group effects and for the positive relationship between R&D and advertising are secured. Considering the complementary relationship of R&D and advertising, it is desirable to analyze R&D and advertising in a same framework.

Since Phillips(1966) proposed that industrial organizations economists should explore the possibility that causality might run from R&D to market structure/performances, many related studies have been issued and provided much theoretical and empirical background on using the SCP paradigm to analyze the effects of R&D. The representative papers which supports the validity of SCP paradigm are as follow: Nelson and Winter(1978, 1982), Mansfield (1983), Geroski and Pomroy(1990), Kamien and Schwarz(1982), and Scherer(1980). In the following sections, this paper introduces a mathematical and statistical models which analyzes R&D and advertising, based on the SCP paradigm.

Section Ⅲ : Mathematical Model for R&D and Advertising

In this section, a mathematical model is introduced and R&D and advertising are analyzed in a same framework. Models are modified for the purpose of analyzing the effects of advertising and R&D under various cases: different functions, static and dynamic, certainty and uncertainty, and one-shot and equal allocation investments. Corresponding results are compared with each other.

Ⅲ.1 Profit-Maximizing Level of R&D(or advertising) Condition

The following profit function shows not only that R&D and advertising can be formulated in a profit function, but that they, as investments, have similar effects on firms' performances.

$$\text{profit}(\Pi) = p\,Q(A, p) - C(Q(A, p)) - A \qquad (\text{Ⅲ}.1.1)$$

where p is price, Q is inverse demand function, and A represents R&D or advertising expenditure. From the FOC (First Order Condition) for maximizing profit where A is the control variable, the following is derived[14].

$$A/pQ = E/e \qquad (\text{Ⅲ}.1.2)$$

The condition (Ⅲ.1.2) shows that a firm will maximize its profit by equating

13) They also show that there is a positive impact of advertising and R&D both on a firm's sales and value in terms of Tobin's q. But the priority of investments falls on R&D in the presence of many government subsidies, and on advertising in case of rare subsidies.

14) Allowing price to vary, the usual standard condition for monopoly pricing can be easily obtained as follows:

$$(p - MC)/p = 1/e$$

where e is the price elasticity of demand for the firm's product.

advertising(or R&D) intensity to the ratio of corresponding elasticity of demand to the price elasticity of demand. This condition which is originated from investigating optimal advertising level, is also called as the Dorfman-Steiner condition which states the profit maximizing level of advertising. If the two elasticities are constant, the optimal ratio of advertising(or R&D) to sales remains constant even if the expenditure of advertising or R&D changes. This condition accordingly provides a solid defense for strategies based on a constant advertising - sales ratio, named as constant advertising intensities. The argument of constant advertising intensity is strongest in case of stable, established products, where advertising and price elasticities may be expected to be subject to only slight variations. For the static and dynamic equilibrium on oligopoly advertising, this condition also provides a rationale for constant advertising-sales ratio at a firm level: Schmalensee (1972).[15] This approach is often criticized for overlooking two important facts that (1) all firms in the real world have limited financial resources and that (2) a firm can take strategic action and/or receive reaction from its rivalry firms.

III.2 Combining Advertising and R&D models under Static

As shown in the previous section, most papers which have been discussed have dealt with either R&D or advertising and its effects on a firm's performances, assuming the unlimited budget. Firms in the real world allocate their available fund both to R&D and advertising investments on which they thrive by increasing profit. Only a few papers deal with R&D and advertising in a same framework: Hergert(1987) and Nakao(1993). This section shows how these two variables, R&D and advertising, can be combined in a statistical model under the assumption of a fixed (limited) budget and how optimal conditions for a firm are derived.

The statistical model to be introduced in this section and hereafter is based on the traditional SCP paradigm under the assumption that winner gains more revenue than before spending on R&D and/or advertising.

At first, this paper adopts general value functions instead of specific functions such as demand function in order to analyze the effects of R&D and advertising in a more general way and find optimizing conditions for a firm maximizing its value from the investments. Later, specific functions for R&D and advertising are introduced so that (1) the existence of solution sets are tested, and (2) implications are derived from the results and compared with each other.

Since Comanor(1965) used an increasing function for R&D, it is a tradition to use quadratic function for R&D. However, the truth is that the square root function explains the

15) Nerlove and Arrow(1962) firstly considered dynamics of advertising by introducing the phenomenon of advertising's lingering effect such as depreciation of goodwill stock and discount rate, while Dhrymes(1962) generalized this model to the case where R&D also have a dynamic effect on demand. Schmalensee(1972) extended Nerlove and Arrow(1962) model by adding time-lag effect of goodwill stock, concluding that the long-run elasticities being constant, neither changes in the interest rate nor fluctuations in the price of advertising will have any impact on the dollar advertising-dollar sales ratio. He thus had the Dorfman-Steiner formula again, except that the short-run elasticities are replaced by long-run elasticities. The optimizing condition for the dynamic case is similarly derived by constructing and solving a Hamiltonian function, under the assumption that at every moment of time(t) there is an equilibrium demand given by $Q^*=Q^*(A, p, t)$ and actual demand, Q, moves toward Q^* at all times:

$$A/pQ = E^*/e^* \qquad \text{where } E^* = (\partial Q^*/\partial A)(A/Q^*) \quad \text{and } e^* = (\partial Q^*/\partial p)(p/Q^*)$$

properties of R&D investment much more than quadratic function with a positive coefficient for a squared variable.[16] Studies of shapes of advertising functions are divided into three groups by how they specify advertising function in the models : linear, square-root, and quadratic. Linear and quadratic advertising functions were used in Schramm and Sherman(1976) and in Hilke and Nelson(1984) respectively.[17] The square-root function has not been used in any mathematical model due to computational difficulties and complicated solution sets. This section treats all three advertising functions along with square root R&D function.[18]

Ⅲ.3 Static Models

<Static model under certainty>

A firm's goal is to maximize the total value, a sum of values from R&D(VR) and advertising(VA) under the assumption of no spill-over effect over time, subject to a budget constraint. This leads to a constraint maximization problem, which can be constructed and solved by using the Lagrangian method.

$$\text{Max } V \text{ subject to } A + R = \overline{M}$$

where V = VA + VR and is the budget.

The following solution represents that a firm will equate the marginal value of R&D to that of advertising in order to maximize the value;

$$V'(A) = V'(R) \qquad (\text{Ⅲ}.3.1)$$

From the condition (Ⅲ.3.1) which is commonly called as the marginal principle, one can infer that the optimizing condition is not affected by the limitation of resources, but by the R&D and advertising and their functional forms. The numerical examples for model 1 and 2 are relatively simple[19] so that much attention has been paid to model 3.

Model 3 to be analyzed is algebraically so difficult that it is impossible to solve the simultaneous system without computing assistance since there is no general solution yet known for the 5th powered equation. Some help from a computer package, Mathematica 2.1 by Wolfram Research, is necessary to solve the equation system and the inequality yet to come.

Only real positive root which is sensible for the purpose of this model is chosen, while other complex roots are dropped. However the chosen root which is real should satisfy some condition to be a positive one.

The solution set is:

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16) The quadratic R&D function means that R&D has the property of increasing return to scale, which is not realistic. Rather, constant return scale or decreasing return to scale reflects the real world better, though there exists economy of scale in R&D investment in a sense.

17) Thomas(1989) statistically shows that the return to scale for advertising is estimated to be decreasing, based on the data of the US sugar and soft drink industries.

18)

Model 1	$V_R = a1 + a2\sqrt{A}$ $V_A = b1 + b2\,A$	where a1 and a2 > 0, b1 and b2 > 0, and b3 < 0.
Model 2	$V_R = a1 + a2\sqrt{A}$ $V_A = b1 + b2\sqrt{A}$	
Model 3	$V_R = a1 + a2\sqrt{A}$ $V_A = b1 + b2\,A + b3\,A^2$	

19) Solution sets for model 1 and 2 are not presented here

$$R\&D^* = [\ \{2(3)^{1/3} b2 + 4(3)^{1/3} b3 M + B^{2/3}\} \ / \ \{2(3)^{2/3}(b3)^{2/3} B^{1/3}\}\ ]^2$$

$$\text{where } B = \{9 (b3)^{2/3} a2 + 3^{1/2} (-8 b2^3 + 27 b3 a2^2 - 48 b2^2 b3M - 96 b2 b3^2M^2 - 64 b3^3 M^3)^{1/2}\}.$$

It is necessary to check whether the solution satisfies the assumptions of real positive root. For simplicity, some numbers are assigned to the coefficients: a2 = b2 = 1 and b3 = −1. It is the necessary and sufficient condition for real positive root that the long and common expression inside the square root of B must be positive. Otherwise this root becomes a complex number. Solving the expression for M, the following is obtained since M is equal to or greater than zero.

$$0 \le M \le \frac{5}{4}$$

The value of B is always positive as long as M is within the above range. The next step is to specify to M a specific number within the range, to solve the model algebraically and to confirm if the system is correct. The unity is assigned for M so that one can check what portion of one unit of fund is allocated to R&D and advertising.[20]

From the solution above, it has been confirmed that this model has at least one equilibrium. In other words, there may be many equilibria under different specifications of coefficient and amount of fund. The proof of existence of a solution set can be an important basis for further analysis later in section Ⅳ.

<Static model under uncertainty>

The effects of R&D, in the degree of risk, is more vulnerable than advertising. To reflect this factor, a hazard function, u(R), is introduced, representing the probability of success. This probability function satisfies the standard properties of a hazard function such that $u'(0) = \infty$, $u'(R) > 0$, and $u''(R) < 0$.

Here the value function is modified by introducing uncertainty factor while leaving the rest same as the former one:

$$V = V_A + u(R) V_R$$

Solving the consequent maximization problem leads to the following;

$$\varepsilon_R = \frac{R}{V(R)\,u} \left[\ V'(A) - uV'(R)\right] \qquad (Ⅲ.3.2)$$

where ε_R is defined as the R&D elasticity of probability of success,

$$\varepsilon_R = \frac{\partial u}{\partial R} \frac{R}{u}$$

From (Ⅲ.3.2), one can infer several strategies of a firm maximizing the value from investments. Consider the case of $\varepsilon_R = 0$ which means that the probability of success is constant. The zero elasticity implies that any increase in R&D spending does not affect the probability of success at all. In this case, a firm will spend on R&D only until the expectation of marginal value from R&D reaches marginal value from advertising;(Ⅲ.3.3). In that case, marginal value from advertising is surely not greater than that from R&D(not expected marginal value). One confirm that marginal principle still holds in this case, too. If $\varepsilon_R = 0$, then

$$V'(A) = uV'(R) \qquad (Ⅲ.3.3)$$

The condition above means that a firm will try to equate the expected marginal return from

20) Numerical solution set for model 3

$R\&D^* = 0.78598, \quad A^* = 0.21402$

R&D to marginal return from advertising to maximize the total value from investment. Condition (Ⅲ.3.3) is similar to the maximizing rule derived in the static case. It is easily confirmed that the optimizing rule for certainty case is a special type of uncertainty cases when u=1 and $\varepsilon_R = 0$. It is also checked that nominal value of marginal benefit from R&D is not less than that of advertising from the following.

$$u = V'(A) / V'(R) \qquad (Ⅲ.3.3')$$

$$\text{and} \quad 0 \le V'(A) \le V'(R) \quad \text{since} \quad 0 \le u \le 1$$

If $\varepsilon_R = 1$, then a firm will allocate its resources such that marginal value from advertising is equal to the sum of expected marginal return(u V'(R)) and expected rate of return from R&D (E_R). The following (Ⅲ.3.4) can be derived from (Ⅲ.3.2).

$$V'(A) = u V'(R) + E_R \qquad (Ⅲ.3.4)$$

$$\text{where} \quad E_R = u \frac{V(R)}{R}$$

For both extreme cases, the models under uncertainty become identical to those under certainty if u = 1. The case of u=0 means that marginal value from R&D(advertising) is infinity(zero); That is, zero R&D expenditure since $u'(0) = \infty$, and all the funds go for advertising.

Now one can derive a generalized form from (Ⅲ.3.2) by using R&D elasticities of return, η_R, and of probability of success, ε_R. The condition (Ⅲ.3.5) shows that a firm's optimizing strategy is related with the degree of uncertainty(ε_R) and the functional forms of advertising and R&D.

$$\begin{aligned} V'(A) &= u\frac{V(R)}{R}(\varepsilon_R + \eta_R) \\ &= E_R(\varepsilon_R + \eta_R) \end{aligned} \qquad (Ⅲ.3.5)$$

$$\text{where} \quad \varepsilon_R = \frac{\partial u}{\partial R}\frac{R}{u} \quad \text{and} \quad \eta_R = \frac{\partial V(R)}{\partial R}\frac{R}{V(R)}$$

Ⅲ.4 Dynamic Models

It is widely known that R&D and advertising have dynamic effects on market performances: Nerlove and Arrow(1962) for advertising[21] and Dhrymes(1962) for R&D. For example, once a firm succeeds in innovating a new technology of reducing cost, then the benefit from it will be collected over time until it becomes obsolete. Here a new concept of present value is introduced as a discounted value over time at a discount rate,.

< One shot investment under certainty >

A firm will maximize the present value discounted at its discount rate subject to the budget constraint. The present value is ;

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21) Nerlove and Arrow(1962) firstly considered the phenomenon of advertising's lingering effect. In their model, firm's demand depends upon a goodwill stock, S, where

$\frac{dS}{dt} = A - \gamma S$, where A is the number of advertising messages and γ is a depreciation rate of goodwill stock. For a dynamic model of R&D, Dhrymes(1962) generalized the dynamic effect of R&D expenditure on demand.

$$PV = \int_0^{\infty} V e^{-\delta t} dt \qquad (Ⅲ.3.6)$$

where PV is a present discounted value, δ is a firm's discount rate, and $V = V_A + V_R$. Now one can construct a simple maximization problem to solve as follows;

Max PV subject to $A + R = \overline{M}$

By the use of the Lagrangian method, three FOC's are derived and solved. The present value and the same optimizing condition as in static case are obtained ;

* present value : {V[R]+V[A]} / δ
* optimizing condition : V'[R]=V'[A]

< One shot investment under uncertainty >

The same method is applied to derive an optimizing condition for One shot investment under uncertainty except the fact that V = V[A] + u[R] V[R]. Again u[R] is a probability of successful innovation. In this case, one also have same results as in static case;

* present value : {V[A]+u[R]V[R]} / δ
* optimizing condition :

$$V'(A) = u \frac{V(R)}{R} (\varepsilon_R + \eta_R) = E_R(\varepsilon_R + \eta_R)$$

$$\text{where } \varepsilon_R = \frac{\partial u}{\partial R}\frac{R}{u} \quad \text{and} \quad \eta_R = \frac{\partial V(R)}{\partial R}\frac{R}{V(R)}$$

Ⅲ.5 Methods of allocation

Now available fund is assumed to be allocated equally over n time periods, starting from the initial time period. At each period, an equal fraction of total fund, m, is allocated both to R&D and advertising such that m = a + r, and returns of corresponding investments over time are summed up by the use of discount rate. The total amount of nominal fund is same as $\overline{M}$= n m = n(a+r). One again evaluate the flow of value in terms of present discounted value. By solving maximization problem similar to the previous ones, the present values and optimizing conditions are obtained as follows[22];

< certainty case >

* Object function

$$\text{Max} \int_0^n \{ \int_t^{\infty} (V[a] + V[r]) e^{-\delta t} dt \} dt \quad \text{subject to } m = a + r.$$

* Solution sets – present value : n { V[a] + V[r] } / δ
  optimizing condition : V'[a] = V'[r]

< uncertainty case >

* Object function

$$\text{Max} \int_0^n \int_t^{\infty} \{ V[a] + u[r] V[r] \} e^{-\delta t} dt dt \quad \text{subject to } m = a + r.$$

* Solution sets – present value : n { V[a] + u[r] V[r] } / δ
  optimizing condition : V'[a] = u[r] V'[r] + u'[r] V[r]

22) the present values under certainty and under uncertainty approach to {V[a]+V[r]}/δ^2 and {V[a]+u[r]V[r]}/ δ^2 respectively as n goes to infinity.

Ⅲ.6 Comparisons

This section evaluates the strategies and their outcomes by optimizing conditions and by magnitudes of discounted presented values. For the detailed method of comparisons, refer to Lee(1994).

For both cases under certainty and uncertainty, the dynamic case appears to have better and at least, equal results in terms of values from investments than the static. The dynamic case will become same as the static case if $\delta = 1$, stating that a firm does not evaluate any future value. It can be said that static results are parts of dynamic analysis. The payoffs from dynamic cases are greater than those from static ones.

One compares the results from One-shot and Equal-Allocation investments under static scheme, which states that any future value, from the firm's point of view, is not discounted and regarded as present value ; $\delta = 1$. Then, the payoffs from various cases under which the discount factor has a range that are compared each other. In static and dynamic cases, the payoffs from equal allocation investment are greater than those from one-shot investment.

In conclusion, both under static and dynamic cases, payoff from equal allocation is greater than that from one-shot investment. Though uncertainty model is superior to certainty one in explaining a firm's behavior, the outcome from the former is bigger than that from the latter.

Section Ⅳ : Statistical Model for R&D and Advertising

The purpose of this section is to estimate the coefficients of specific functions shown in the previous section and to test the hypotheses of individual effects by industry, firm size, and type of products. The marginal principle which is a result of the previous theoretical analysis is also checked to show whether it is adequately applied to Korean firms or not. The model in this paper is similar to the econometric models of Thomas(1989) and Nguyen(1987) in that both papers use a single equation model system, and have sales as dependent variable.

Ⅳ.1 Data and Variables

The firm-level data come from the annual reports of the listed firms on the KSE(Korean Stock Exchange) and by the KPC(Korean Productivity Center). Annual data of 84 leading firms in the 27 industry groups are selected during the period of 1989-1991,[23] resulting in a sample size of 252. These firms are chosen by their data availability and credibility.[24] Price data to be used to adjust financial values of variables are drawn from the IFS (International Financial Statistics) Annual Report of 1993 published by IMF(International Monetary Fund).

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23) There were 689 firms listed in the KSE as of the end of 1991. Out of 31 industry groups classified by the KSE, banking, securities and investment banking, insurance, and recreation industries, 88 firms in these industries, are excluded for their lack of data on R&D and advertising. The firms of which securities are under surveillance or have ever been stopped and/or delisted during 1989-'91(56 cases) are also excluded. To keep the data consistent, any firms which had M&A transaction are excluded from the selection of data. The number of firms is eventually 84 out of 545, 15.4 % of the population.

24) Any firm listed in the KSE is required to report in advance any significant decisions by the firm such as raising capital, stock-splitting, and merge and acquisition(M/A) as well as its B/S (Balance Sheet) and P/L (Statement of Profit and Loss) to the KSE to keep itself listed.

AD is advertising investment and RD is R&D investment, while ADSQ(RDSQ) is the squared AD(RD) and RDST is the square root of RD. EXPR is firm's export ratio to sales. ADSQ(RDSQ) is the product of AD(RD) and SZ which is zero for big firms and one for small firms, while ADCON(RDCON) is the product of AD(RD) and CON which is zero for firms producing producer good and one for firms producing consumer good.

Ⅳ.2 Descriptive Statistics

Descriptive statistics which is categorized by industry, by firm size, and by the type of products is shown in the following three tables.

According to Table Ⅳ-1, textile (8.2706), paper product (12.5529), pharmaceutical (10.3646), cosmetics (5.7373), and medical/optical (4.1696) industries have much higher advertising intensities than industry average(2.3275), while mining, rubber and plastic, basic metal, electricity, computer and motor sales industries have lower intensities. The industries with higher advertising intensities than industry average are undergoing fierce competition. Six industries with low advertising consist of those which produce producer's good or concentrate on R&D. In terms of R&D intensity, pharmaceutical (1.0377), cosmetics (1.2409), computer (1.1241), and motor and transportation (1.7770) industries are spending more money on R&D investment than the industry average (0.3347). It is well known that these industries are pressured to have new brands and to come up with innovated products.

Table Ⅳ - 1 Descriptive Statistics by Industries

unit:10bil.won,%

Industry	# of Obs	Sales	Advertising Expenditure	R&D Expenditure	Advertising Intensity(A)	R&D Intensity(B)	Ratio (A/B)
1	9	9.9	0.265	0.001	2.6717	0.0091	293.89
2	6	8.0	0.007	0.001	0.0903	0.0113	8.00
3	18	30.6	1.134	0.137	3.7019	0.4476	8.27
4	24	29.4	0.261	0.092	8.2706	0.3131	26.41
5	9	15.4	0.181	0.022	1.1785	0.1414	8.34
6	3	2.6	0.320	0.001	12.5529	0.0549	228.64
7	6	193.7	0.571	0.343	0.2945	0.1769	1.67
8	9	33.8	0.256	0.077	0.7586	0.2266	3.35
9	6	11.4	1.183	0.118	10.3646	1.0377	9.99
10	6	20.3	1.167	0.252	5.7373	1.2409	4.62
11	9	5.6	0.012	0.008	0.2147	0.1503	1.43
12	9	23.6	0.244	0.130	1.0300	0.5482	1.88
13	6	283.0	0.223	0.188	0.0789	0.0663	1.19
14	12	10.3	0.038	0.021	0.3681	0.2074	1.77
15	6	11.0	0.243	0.124	2.1975	1.1241	1.95
16	9	26.7	0.135	0.010	0.5064	0.0374	13.53
17	24	132.9	1.976	0.168	1.4865	0.1263	11.77
18	6	7.4	0.310	0.009	4.1696	0.1263	33.03
19	18	163.1	0.731	2.898	0.4485	1.7770	0.25
20	9	10.4	0.298	0.027	2.8644	0.2606	10.99
21	3	510.1	0.308	0.588	0.0604	0.1153	0.52
22	15	82.7	0.081	0.122	0.0983	0.1477	0.67
23	3	186.5	0.353	0.001	0.1893	0.0005	392.33
24	18	262.0	0.873	0.121	0.3332	0.0461	7.22
25	3	17.6	0.104	0.061	0.5920	0.3465	1.71
26	3	8.5	0.081	0.021	0.9471	0.2503	3.78
27	3	174.9	2.864	0.079	1.6381	0.0454	1.64
	252	84.12	0.526	0.208	2.3275	0.3347	39.96

Firms can be also divided into two groups by the firm size, small and big. Table IV-2 shows that big firms have a balanced investment pattern for R&D and advertising: the intensity ratio is 1.42. Small firms concentrate on advertising than R&D investment, relatively and absolutely: their intensity ratio(4.39) is well above the overall average(2.03). Though small firms' R&D intensity (0.550) is clearly higher than big firms' (0.342), it is inappropriate to conclude that small firms are efficient to innovate, because (1) small firms are gathered in pharmaceutical, cosmetics, and computer industries which have the property of high R&D investment, and (2) the data shown here has not given any evidence to which firms, big or small, are successful in R&D. The high intensity ratio(A/B) for the small firms is due to textile, paper product, and medical/optical industries which heavily depend on advertising. Only what we can say is that firms do not increase their investments in R&D and advertising as much as their sales do.

Table IV - 2 Descriptive Statistics by Firm Size

unit : 10 bil. won, %

Firm Size	# of Obs	Sales	Advertising Expenditure	R&D Expenditure	Advertising Intensity(A)	R&D Intensity(B)	Ratio (A/B)
Big	81	218.03	1.061	0.746	0.486	0.342	1.42
Small	171	16.61	0.401	0.091	2.414	0.550	4.39
Overall	252	81.35	0.613	0.302	0.754	0.371	2.03

Table IV - 3 Descriptive Statistics by Type of Products

unit : 10 bil. won, %

Type of Products	# of Obs	Sales	Advertising Expenditure	R&D Expenditure	Advertising Intensity(A)	R&D Intensity(B)	Ratio (A/B)
Producer	93	60.39	0.198	0.109	0.327	0.154	2.12
Consumer	159	93.61	0.856	2.294	0.914	0.453	2.02
Overall	252	81.35	0.613	0.302	0.754	0.371	2.03

IV.3 Estimation

This section consists of three parts: (1) estimation to find the best-fitting functions for R&D and advertising, (2) various tests for appropriate regression model, FEM(Fixed Effects Model) or REM(Random Effects Model), and (3) estimation of the model chosen in (2) using the functions in (1) by industry, firm size, and type of products.

Firstly, we estimate specific functions to examine the relationship between firm's sales and its R&D and advertising expenditures. The basic model to be used is as follows:

$$Y_{it} = \alpha + \beta x_{it} + \varepsilon_{it} \qquad \text{(IV-1)}$$

for i = 1 to N and t = 1 to T

where α and β are coefficients,

and $E[\varepsilon_{it}] = 0$ and $Var[\varepsilon_{it}] = \sigma^2$

IV.3.1 Evidence from Pooled Data

To estimate the above model, OLS(Ordinary Least Squares) is employed. Estimation is by an OLS regression of y_{it} on a single constant and the set of x's. For this model, the group and firm specific nature of the data set is temporarily ignored.

From Table Ⅳ-4, one can see that a quadratic function for advertising and a square root function for R&D are shown to be best fitting in explaining dependent variable. Both R&D and advertising expenditures take their expected signs in all models except ADSQ in model 5.

Table Ⅳ- 4　　Summary of Estimation using Ordinary Least Squares

Explanatory variable	Dependent variable : SALE					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
CONSTANT	0.1013 (0.832)	0.0510 (0.378)	-0.1545 (1.132)	0.0133 (0.098)	-0.2592 (1.755)	0.3285 (2.272)
AD	0.5212 (6.625)	0.6549 (3.791)	0.5228 (3.051)	0.6257 (3.612)	0.4896 (0.389)	1.1324 (5.639)
ADSQ	-	-0.0240 (0.867)	-0.0149 (0.552)	-0.0235 (0.852)	0.9536 (0.685)	-0.0958 (3.299)
RD	0.4190 (5.551)	0.4073 (5.308)	-	0.8110 (3.028)	-	-
RDST	-	-	1.2442 (6.652)	-	1.9483 (3.122)	1.1052 (5.856)
RDSQ	-	-	-	-0.0567 (1.573)	-	-
EXPR	0.0103 (3.295)	0.0106 (3.369)	0.0108 (3.509)	0.0109 (3.446)	0.0110 (3.587)	0.0027 (1.913)
ADSZ	-	-	-	-	-	-1.4285 (3.522)
S.E.	1.2880	1.2886	1.2526	1.2848	1.2404	1.1254
R^2	0.297	0.299	0.338	0.306	0.359	0.479

Statistics in the parenthesis are *t*-values.

As an alternative to choosing the best fitting function , one can use an elasticity approach. Using the regression results from same model 1 to 6 presented as in Table Ⅳ-4, R&D and advertising elasticities of sales ($\theta_{AD} = \frac{\partial SALES}{\partial AD}\frac{AD}{SALES}$ and $\theta_{RD} = \frac{\partial SALES}{\partial RD}\frac{RD}{SALES}$) can be calculated respectively. For calculating the elasticities, the partial derivatives can be easily obtained from the corresponding regressions and average values are used for AD, RD and SALES.

According to Table Ⅳ-5, quadratic advertising function is preferred to linear one. To compare three different R&D functions, R&D elasticity in model 3 which includes a square root R&D function is biggest among three models. The significant size of R&D elasticity in model 5 and 6 supports the use of a square root R&D function.

Table Ⅳ-5　　Advertising and R&D Elasticities

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Advertising	0.00393	0.00472	0.00450	0.00380	0.01250	0.0765
R&D	0.00051	0.00050	0.00241	0.00099	0.00377	0.00214

Model 1 to 6 have same variables as in Table Ⅳ-4.

Ⅳ.3.2 Fixed Effect Models(FEM)

One of the advantages using panel data is that one can correct for heterogeneity across firms. The basic model is constructed as follows:

$$y_{it} = \alpha_i + \beta x_{it} + \varepsilon_{it} \qquad (Ⅳ-2)$$

for i = 1 to N and t = 1 to T
where α and β are coefficients,
and $E[\varepsilon_{it}] = 0$, and $Var[\varepsilon_{it}] = \sigma^2$

In the above (Ⅳ-2), $\alpha_i = \bar{\alpha} + \mu_i$ is the intercept for ith firm, $\bar{\alpha}$ is the mean intercept, μ_i and represents the difference from this mean for i th firm.

The appropriate estimation procedure for the model (Ⅳ-2) depends upon whether are assumed to be fixed or random. If the μ_i are assumed to be fixed, estimation of (Ⅳ-2) with a fixed effects estimator is preferred. If the μ_i are assumed to be random, the use of a random effects or error component models is demanded. It is widely recognized that the REM is used if the $\mu_i \sim i.i.d.(0, \sigma^2_\mu)$ is assumed and the number of individuals(N) is sufficiently large for reliable estimation of a σ^2_μ; when μ_i and x_{it} are correlated, or N is small, the FEM is used.[25] In order to test the hypothesis that the μ_i and x_{it} are uncorrelated, a Hausman test(Hausman(1978) and Taylor(1981)) is used. Specifically, they suggest a test statistic which has an asymptotic χ^2 distribution under the null hypothesis that there is no correlation between X's and firm effects. The test statistic, which is called m-statistic, can be calculated as follows:

$$m = (b - \hat{\beta})' (M_1 - M_0)^{-1} (b - \hat{\beta})$$

where b and $\hat{\beta}$ are FE and GLS estimators,
M_1 and M_0 are their covariance matrices respectively as

$$M_1 = \sigma^2_e \, [X'(I_N \otimes D_T)X]^{-1}$$

$$M_0 = \left[\frac{1}{(T\sigma^2_\mu + \sigma^2_e)} X'Q_1 + \frac{1}{\sigma^2_e} X'(I_N \otimes D_T)X \right]$$

where I_N is an identity matrix and D_T and Q_1 are the idempotent matrices that transform the observations on each individual so that they are in terms of deviations around the mean for that individual.[26]

Hausman test statistics using model (Ⅳ-2) shows that models by size and by the types of products are favorable to the FEM,[27] while the REM is not rejected for the model

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25) However, Chamberlain(1978) and Hausman and Taylor(1981) noted that there are two possible undesirable features of the FEM estimators when μ_i and x_{it} are correlated. First, if x_{it} contains some time invariant variables, it is impossible to separate these variables from the dummy variables. Individual effects are eliminated when the within estimator is obtained. Secondly, it may be less efficient than alternative consistent estimators that exploit information on the relationship between μ_i and x_{it}, and do not ignore sample variations across individuals.

26) $D_T = I_T - \frac{j_T j_T'}{T}$ and $Q_1 = I_N \otimes \frac{j_T j_T'}{T} - \frac{j_{nt} j_{NT}}{NT}$, which are idempotent matrices where j_T = (1,1,1,............,1)'.

27) The value for Hausman statistics for industry is zero, so the hypothesis that there is no correlation between the μ_i and x_{it} is not rejected. The LM(Lagrange Multiplier) Tests developed by Breusch and Pagan(1979) lead to same results. For firm size and type of products, FEM is the only choice available because the variances in the corresponding REM's have negative values.

by industries. Even in the model by industries, the REM estimators are not significantly different from those of the FEM. Estimation results by the REM model are listed later in Table IV-6. Mundlak(1978) suggests that the FEM is favorable, because though the GLSE(Generalized Least Squares Estimator) is BLUE, the REM ignores the possible correlation between μ_i and x_{it}. From now on, this paper concentrates on the FEM.

Fixed effects models are estimated by industries, firm size and types of products firms produce, consumer and producer goods. The theoretical background for the industrial fixed effects can be found in Hergert(1987).[28] According to him, R&D and advertising are the biggest factors which create group effects in industries. Mundlak(1961) showed that the estimates from a least squares regression with individual specific intercepts, fixed effects, are consistent ones of β.[29] The model (IV-2) is also called as the 'Least Squares Dummy Variables' model.[30] Parameters are estimated by following two step procedures. First, β is estimated from a regression of $(y_{it} - \bar{y}_i)$ on $(x_{it} - \bar{x}_i)$ with no constant term. Second, α_i is estimated from $\bar{y}_i - \hat{\beta}' \bar{x}_i$.

Model 1 in Table IV-6 shows that estimates by the FEM and the REM are very similar to each other; AD, RDST, and EXPR are significant at 5% level. According to model 2, the introduction of interacting variables brings out better results than in model 1; (1) lower standard errors (0.831 to 0.773) and higher R squared(0.745 to 0.785), (2) ADSQ which is not significant in model 1 becomes significant in model 2, (3) new interacting variables such as ADSZ and RDSZ are significant at 5% level. Among the individual effects by industries which are significant, four industries, basic metals, electricity, motor sales, and wholesale, retail, and trade, have positive effects while another four industries, textile, chemicals, communication (including radio and TV) equipment, and transport services, have negative ones. One can infer that the effects for the first two industries may come from their heavy R&D investments while the last two industries' effects from their advertising efforts. All the industries having significant negative effects are related with allegedly heavily advertising. These industries except chemicals also have higher advertising intensities and higher ratios of advertising to R&D intensities than overall average.[31]

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28) Hergert(1987) shows what makes the industrial group effects among the US firms as follows:

	Advertising	R&D	Market share	Capital Intensity	Sales ratio
Frequency, %	45	48	30	20	31

Note : 1) The sales ratio is a business unit sales as a percent of parent company sales.
2) 45% for advertising means that in 45% of the industries, advertising provided a significant basis for group effects.

29) In his production function example, Mundlak(1961) generalized this estimator which can be obtained from a least squares regression with individual effects, when T>2. Later on, he improved his favor for the FEM theoretically in Mundlak(1968) and Mundlak(1978).

30) The equation (4-2) can be written as follows:

$$y_{it} = \alpha_i + \beta' x_{it} + \varepsilon_{it}$$
$$= \sum_{j=1}^{N} d_{ji} \alpha_j + \beta' x_{it} + \varepsilon_{it}$$

where d_j's are dummy variables which are 1 only when j = i, and otherwise zero.

31)

	Advertising Intensity (A)	R&D Intensity (B)	Ratio(A/B
transport	1.64	0.04	36.1
textile	8.27	0.15	26.4
communication (TV and Radio)	1.49	0.07	11.8
chemicals	0.76	0.16	3.4
overall	0.75	0.37	6.8

The test results, Chi-squared and F statistics, both reject the hypothesis of no group effects: the hypothesis that estimates for model (4-1) are equal to those for model (4-2).

Table Ⅳ - 6　　Estimating Fixed Effects by Industries

Explanatory Variables	Dependent Variable : SALES				
	Model 1			Model 2	
	OLS	FE	RE	OLS	FE
CONSTANT	-0.1544 (1.132)	-	-0.2720 (1.161)	0.2389 (1.511)	
AD	0.5228 (3.051)	0.9227 (5.043)	0.7851 (4.542)	1.1669 (5.558)	1.2055 (6.006)
ADSQ	-0.0149 (0.552)	-0.0502 (2.006)	-0.0358 (1.486)	-0.0922 (3.178)	-0.0879 (3.292)
RDST	1.2442 (6.652)	0.9000 (4.386)	1.0380 (5.254)	1.5793 (2.655)	1.8227 (2.789)
EXPR	0.0108 (3.509)	0.0223 (6.453)	0.0195 (5.923)	0.0033 (3.077)	0.0156 (4.085)
ADSZ				-0.9207 (4.135)	-0.8678 (3.610)
ADQSZ				0.2226 (1.323)	0.1340 (0.764)
RDSZ				-1.3245 (3.155)	-1.6048 (3.666)
RDCON				-0.4871 (0.822)	
S.E.	1.253	0.831	0.831	1.128	0.773
R^2	0.338	0.745		0.467	0.785

Statistics in the parenthesis are t-values.

According to Table Ⅳ-7, the variables such as AD, ADSQ and RDST are significant as in the FEM by industries. Among interacting variables, ADSZ is significant at 1% while RDSZ at 5% as shown in the above table. Negative coefficients for ADSZ represent that the small firms receive smaller increase in sales from additional advertising than big firms, and that the bigger firms invest more on advertising than the small firms. Similar explanation is also applied for negative coefficient for RDSZ. The group effects between large and small firms are significantly different from each other and the effect for big firms is significant at 1% level: the fixed effect for large firms is 1.0036 (4.233) while -0.0464 (0.277) for small firms.[32] The fixed effect for large firms is positive and statistically significant while the FE for the small is negative but not significant. The big firms spend both on R&D and advertising, and enjoy the advantage of it. This may be interpreted as a barrier to entry. The null hypothesis of no group effects is also rejected.

32) Statistics in the parenthesis are t-values.

Table IV - 7 Estimating Fixed Effects by Firm Size

	Model 1		Model 2	
	OLS	FE	OLS	FE
CONSTANT	-0.1544 (-1.132)	-	0.2441 (1.829)	-
AD	0.5228 (3.051)	0.3712 (2.459)	1.1175 (5.558)	0.7237 (3.453)
ADSQ	-0.0149 (-0.552)	-0.0080 (-0.338)	-0.0992 (3.178)	-0.0499 (2.711)
RDST	1.2442 (6.652)	0.7310 (4.204)	1.1582 (6.233)	0.8236 (4.304)
EXPR	0.0108 (3.509)	0.0064 (2.336)	0.0033 (1.130)	0.0042 (1.381)
ADSZ	-	-	-0.9207 (4.135)	-0.4828 (2.649)
ADQSZ	-	-	-0.2462 (1.496)	-0.0241 (0.142)
RDSZ	-	-	-1.3578 (3.233)	-0.5972 (2.316)
S.E.	1.253	1.096	1.128	1.081
R^2	0.338	0.495	0.467	0.513

Statistics in the parenthesis are t-values.

Table IV-8 shows that ADSZ and RDSZ are significant at the 1% significant level and RDCON is significant at 10%. The negative and significant estimate for RDCON implies that the firms producing consumer's goods are likely to invest less on R&D than the firms producing producer's goods. The fixed effect for the firms producing consumer's goods is positive and significant at 5% while the effect for the firms producing producer's goods is not significant.[33]

33) The FE by Types of Goods

	Fixed Effects	t-values
Firms producing Porducer's goods	0.05194	0.242
Firms producing Consumer's goods	0.45721	2.385

TableⅣ-8 Summary of Estimating Fixed Effects by Type of Products

	Model 1		Model 2	
	OLS	FE	OLS	FE
CONSTANT	-0.1544 (-1.132)	-	0.2389 (1.002)	-
AD	0.5228 (3.051)	0.6055 (3.328)	1.1669 (4.558)	1.1257 (5.501)
ADSQ	-0.0149 (-0.552)	-0.0242 (-0.871)	-0.0803 (3.125)	-0.0931 (3.175)
RDST	1.2442 (6.652)	1.2452 (6.669)	1.5793 (2.655)	2.1720 (3.281)
EXPR	0.0108 (3.509)	0.0113 (3.654)	0.0033 (3.077)	0.0034 (0.629)
ADSZ	-	-	-0.9207 (4.135)	-0.9127 (4.043)
ADQSZ	-	-	0.2226 (1.323)	0.3167 (1.821)
RDSZ	-	-	-1.3245 (3.155)	-1.2950 (3.101)
RDCON	-	-	-0.4871 (-0.822)	-1.1607 (-1.708)
S.E.	1.253	1.251	1.128	1.130
R^2	0.338	0.343	0.467	0.487

Statistics in the parenthesis are t-values.

Regarding the firms producing consumer's good, they are estimated to spend less on R&D and their fixed effects are significant. These two facts lead to the conclusions that those firms concentrate more on advertising to promote their sales rather than on R&D and that advertising is more responsible for fixed effects than R&D. The second conclusion is different from that of Hergert(1987) in which R&D is more effective than advertising.

Though the FEM does not result in much improvement in explaining power, even loss in efficiency due to bigger standard error, the FEM in model 2 in Table Ⅳ-8 is tested to have significantly different estimates from the OLS model; this significance is secured by introducing interacting variables such as ADSZ, RDSZ, and RDCON because the test result for model 1, which has no interacting variables, shows no difference between the OLS model and the FEM. Both likelihood ratio and F-statistic tests support the use of model 2 for the FEM by type of products: model 2 is preferred to model 1.

Ⅳ.4 Confirming the Marginal Principle

One of the important conclusions in section Ⅲ is the marginal principle that a firm will allocate its financial resources until the marginal value of advertising is equal to that of R&D. In this section, the estimated functions in the previous section are used to confirm whether or not these functions numerically fulfill the marginal principle. The marginal values of R&D are shown to be bigger than those of advertising.[34] This fact can be

34) Marginal Values by Industries, Sizes, and Type of products

	Industry	Size	Type of Products
Marginal Value of Advertising	1.098	0.663	1.012
Marginal value of R&D	2.893	1.307	3.519

explained by two reasons. One is that higher marginal values of R&D is the result of ignoring the uncertainty factor in R&D investment. The introduction of probability of successful R&D result could have reduced the marginal values of R&D. The other is the possibility of excessive advertising. Advertising can be easily adopted as a strategy promoting sales for its safety and cost advantage, compared with R&D.

Section V : Concluding Remarks

This paper formulated a rule of decision making on investments of R&D and advertising in the SCP(structure-conduct-performance) framework in which those investments affect firms' performances through increasing demand, reducing cost, and creating barriers to entry. Both a mathematical and a statistical models were employed in order to analyze a firm's behavior facing investment in R&D and advertising, and their effects on market performances.

The mathematical model demonstrated that (1) the marginal principle holds as an optimizing condition for a firm recognizing the relationship between R&D and advertising, which is also true in the cases of static and dynamic analysis, (2) the model under uncertainty showed that the condition is affected by the R&D elasticity of success, and that the model under certainty is a part of many possible models under uncertainty, and (3) by assigning specific functions for R&D and advertising, the mathematical model is proved to have at least an equilibrium and the method of equal allocation is superior to one-shot spending when it comes to the choice of investment strategy. It was also showed in the statistical model that (1) R&D and advertising as well as export ratio are the significant variables in explaining a firm's performance in terms of sales, (2) a square root and quadratic functions are estimated as best fitting for R&D and advertising respectively, and (3) among the group effects considered using the FEM(Fixed Effects Model), fixed effects by industry and firm size are estimated as significant, while types of product is not.

This paper took only one example to prove the existence of the equilibrium of the mathematical model. This was done for convenience sake because by assigning some specific numbers to the coefficients of the functions, one can easily show that many a new and corresponding equilibrium can be obtained in different models. This paper did not carry out the empirical test on the advantage of equal allocation method over one-shot spending which was shown in the mathematical model. That test procedure requires more data over time and econometric technique of time series so that it could have been an independent paper. Finally, it must be pointed out that a firm investing in R&D and advertising is assumed to have perfect knowledge on the process and the results. This assumption is so strong that one may come up with different results from those in this paper by varying the degree of a firm's knowledge in the whole process and the results.

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<연구관심분야>

기술경제, 국제경제, 응용계량경제

<주요연구활동>

- ◆ 환율지수평가로 본 원화환율의 적정수준 평가(1990)
- ◆ An Empirical Test of the Efficiency of Exchange Rate Policy in Korea(1992)
- ◆ Testing the Generalized Marshall-Lerner Condition(1993)
- ◆ Advertising and R&D in Korea: Mathematical and Statistical Models(1994)

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