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R&D and market value: appropriability vs. preemption[1]

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February 2004

Summary

The recent empirical studies on innovation and market value suggest that R&D has a strong complementarity with market share in the market valuation of firms. Blundell, Griffith and Reenen (1999) argue that it represents the strategic preemptive effect, while Hall and Vopel (1997) suggest a Schumpeterian reason (the cost of financing R&D is lower for large firms). The theoretical framework of these studies is the classical work by Griliches (1981), which postulates that the market value of a firm is given by the sum of the values of physical capital and R&D capital with respective multipliers. However, non-rivalry in using new knowledge within a firm makes this framework highly questionable. This paper examines the nexus between R&D and market value, based on a simple but new structural model. Major findings are the following. First, the new model shows that the market evaluation of R&D may well be high for a firm with a large market share, simply due to its appropriability advantage. Second, our estimation based on the data of the Japanese firms shows that the new specification performs better. Third, it shows that there is no statistical support for the prevalence of preemption effect.

Key words: R&D; market value; appropriability; preemption

JEL classification: L10, O32

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I. Introduction

The recent empirical studies on R&D and market value suggest that R&D has a strong complementarity with market share in the stock market valuation of firms[i]. More specifically, while a firm with a large market share tends to enjoy high market valuation of both tangible and R&D investments, such effect looks to be especially strong for R&D investment. Such relationship was first pointed out by Blundell, Griffith and Reenen (1999) based on their study of British manufacturing firms for the time period of 1972-1982. They found that the interaction term between market share and R&D variable had a significantly positive coefficient in the equation explaining the market value of a firm, even controlling the effects of market share and R&D individually. Hall and Vopel (1997) confirmed such relationship, based on their study of US firms for the time period form 1987-1991, although Toivane, Stoneman and Bosworth (2002) did not find it from the more recent (1989-1995) data of UK firms. Blundell, Griffith and Reenen (1999) argue that their finding that the marginal return of R&D is high for a firm with large market share represents the strategic preemption effect or efficiency effect due to Gilbert and Newbery (1982). Hall and Vopel (1997) suggest a Schumpeterian reason (the cost of financing R&D is lower for large firms), given their finding that the marginal return of R&D depends more on firm size than on market share[ii].

These studies, however, may have the following fundamental problem. Their estimation is based on the model of market value determination, which treats R&D investment in the same manner as tangible investment. In particular, they are based on the classical work by Griliches (1981), which postulates that the market value of a firm is given by the sum of the values of physical capital and R&D capital with respective multipliers. However, knowledge created by R&D has a unique characteristic that its use is non-rival, i.e. the expansion of its use within a firm costs nothing, unlike investment in plant and equipment. Consequently, the linear homogeneity assumption of the profit function which is an essential assumption of the concept of the capital aggregate (Hayashi and Inoue (1991)) does not hold, when the capital of a firm consists of both knowledge and tangible capital. Thus, the above market power interpretation of the nexus between R&D, market share and market value may depend on a wrong underlying model.

This paper attempts to investigate this nexus by developing a structural model of market value determination as well as by providing the estimates based on that model. First, it presents a simple structural model, which explicitly takes into account the non-rivalry in using knowledge within a firm. The model shows that the stock market evaluation of R&D can be high for a firm with a large market share, simply due to its appropriability advantage. Second, it estimates the model explaining the market value of a firm, based on both conventional specification due to Griliches (1981) and on the new specification, using the data of the Japanese firms (1991-2000). It shows that the new specification does better than the conventional one in explaining the market value of a firm. While it confirms that the relationship found by Blundell, Griffith and Van Reenen (1999) holds for the Japanese industry, it also shows that the interaction term between market share and R&D has a larger coefficient for the sub-sample of the firms with lower market shares. Third, we evaluate the effect of interaction term between market share and R&D, based on the "true" model of market value determination, and finds that a firm with larger market share has actually a lower marginal return from R&D.

The rest of the paper is organized in the following manner. Section II presents an analytical framework. Section III discusses empirical specification and data and section IV presents the estimation results and discuss them. Section V concludes.

II. Analytical framework

First, let us describe the conventional specification, the origin of which is Griliches (1981). The market value of a firm is given by the following specification.

$$V = \theta(K + \lambda IK) \quad (1)$$

where K is the value of tangible capital stock, IK is the value of intangible capital stock, λ is the relative shadow price of intangible asset, and θ represents the divergence between the market value of a firm and the sum of its tangible and intangible capital stocks. θ is supposed to reflect both the monopoly position of a firm and the risk it faces. Defining Tobin's q as the market value relative to the tangible capital stock ($q = V / K$), we have

$$q = \theta(1 + \lambda IK / K) \quad (2)$$

Taking the logarithms of both sides, and assuming that $\lambda IK / K$ is significantly less than 1, we have

$$\ln q = \ln(V / K) \cong \ln\theta + \lambda IK / K \quad (3)$$

In this framework a firm with high market power (higher θ) can generate more profit from both tangible and intangible capital stocks. Reflecting this, empirical studies have postulated that market share is one determinant of θ (see, Jaffe (1986), Hall and Vopel (1997), Blundell, Griffith and Van Reenen (1999) and Toivane, Stoneman and Bosworth (2002)). If a firm with market power can generate profit from its intangible capital stock on top of this effect, the market share would increase not only θ but also λ. Blundell, Griffith and Van Reenen (1999) finds empirical evidence supporting this, and argue that this shows the preemptive effect of R&D by a firm with market power, given that the appropriability advantage of such firm is being controlled by a market share variable as affecting θ.

The conventional model, however, has the following two problems. First, R&D investment is treated in the same manner as tangible investment, so that non-rivalry in using new knowledge within a firm is ignored. Second, market power is exogenous with respect to R&D investment. As an alternative, we consider the following structural model, which explicitly takes into account these two aspects. We consider a two-period model for simplicity. Both tangible and intangible investments are made in the first period and output is produced in the second period. c represents constant marginal capital cost of production, p is the market price of a product(net of the payment of non-capital costs such as material, utility and labor costs), y is the output, K is tangible capital stock at the end of the first period (investment in the first period), IK is the intangible capital stock at the end of the first period (investment in the first period), Π is the profit in the entire periods, V is the market value of the firm at the end of the first period. The tangible capital stock K necessary to produce y in the second period is given by

$$K = cy \qquad (4).$$

Assuming that interest rate is zero for simplicity, we have

$$\Pi = (p - c)y - IK = py - K - IK \qquad (5)$$

$$V = py = K + IK + \prod \qquad (6).$$

Thus, Tobin's q in this specification is given by

$$q = V / K = py / cy = p / c \quad (7)$$

R&D has the effect of increasing (expected) price cost margin (*p/c*) and thus *q*. In the context of competition for a drastic innovation a firm with larger R&D has a higher probability to win the race, so that it is more likely to enjoy a monopoly position. Alternatively, in the context of competition through non-drastic innovations, such firm is more likely to have quality and/or cost advantage. Thus, we have the following specification of Tobin's *q*, taking into accounts of a possible diminishing return of such investment as well as the negative effect of supply expansion on price (see the Appendix for elaborations):

$$q = 1 + (p - c)/c = 1 + \beta_0 + \beta_1 IK - 1/2\beta_2 (IK)^2 - \beta_3 K \quad (8).$$

β_0 reflects both the effects of industry R&D investment on the price cost margin of the firm as well as the effect of non-R&D advantages of a firm such as more efficient labor use (note that *p* is net of material and labor costs). We expect that $\beta_1 > 0$, $\beta_2 > 0$ and $\beta_3 > 0$. Note that we have an implicit assumption here that a firm appropriates the return from its intangible investment only by using the knowledge for its production.

Combining equations (7) and (8), we have

$$V = K(1 + \beta_0 + \beta_1 IK - 1/2\beta_2 (IK)^2 - \beta_3 K) \quad (9)$$

Although *K* and *IK* are jointly determined to maximize *V*, *K* is partially exogenous with respect to *IK*, since non-R&D advantage such as efficient use of manufacturing labor increases the level of *K* for a given *IK*. For an example, a firm with lower non-capital costs should have higher price *p* (higher β_0), so that it would have a higher level of tangible capital for a given level of R&D investment (it is easy to show that the profit maximizing K increases with β_0 from equation (9)). Larger K in turn improves the marginal return of R&D investment. Thus, a firm with larger complementary asset (due to lower non-capital costs) can exploit more effectively the knowledge generated by R&D, due to non-rivalry in the use of knowledge within a firm.

There is a very significant difference between the conventional model and the new model in the following respect. What mattes in the determination of q is the ratio between intangible capital stock and tangible capital stock in the conventional specification (equation (2)), while it is the absolute level of intangible capital stock according to the new model (equation (8)). To put it in another way, what matters in the determination of the market value of the firm is the intangible capital stock according to the conventional specification, but it is the product of tangible and intangible capital stocks in the new specification. The difference arises due to the following reason. In the new specification, the intangible capital stock or knowledge affects price cost margin, and the market value of a firm depends on the product between its price cost margin and the size of its tangible capital stock. Thus, a large firm (due to low non-capital costs) has the advantage that it can more extensively use knowledge as reflected in price cost margin. On the other hand, intangible capital stock is treated as an addition to tangible capital stock in the conventional specification, reflecting its basis on an accounting formula, so that the above effect is lost.

The new model (equation (8) or (9)) provides a straightforward explanation why the stock market evaluation of R&D is found to be high when a firm has a large market share. This is based on the appropriability advantage of such firm: the firm with large tangible capital stock (thus, a firm with a large market share in an industry) can more effectively translate the knowledge created by intangible capital stock in the profit, although we have to note that the level of tangible capital stock is partially endogenous to intangible investment. Thus, it is unnecessary for us to resort to the preemptive motivation of a firm for explaining the larger effect of R&D investment of the firm with a larger market share.

In the long run equilibrium the profit will be dissipated though competition (investment and entry). If such dissipation is perfect, price is equal to average cost[iii]. Assuming this, the longrun Tobin' q (q_{LR}) is given by

$$q_{LR} = V / K = 1 + IK / K \qquad (10)$$

Thus, what determines q in the longrun in this case is the ratio between intangible capital and tangible capital. Equation (10) is identical to Equation (3) when both λ and θ are unity. Thus, if this longrun relationship prevails, the rejection of the conventional model would become difficult. However, if we focus on short-run changes over time such as within-firm variation in a few years time interval, the above longrun relationship (equation (10)) would be less binding. Thus, panel estimation with fixed effects would help us to identify the conventional and new models. On the other hand, cross section estimation may provide biased support to the conventional model, since missing variables such as management capability may be more correlated with the relative R&D investment than with the absolute level of R&D.

III. Empirical specification and data

In this section, we will establish the following three findings. First, we show that the conventional model due to Griliches (1981) is dominated by the new model proposed in the last section in explaining the market value of a firm. Second, using the conventional specification, we show that the interaction term between market share and R&D variable is more significant for the sub-sample of the firms with the smallest market shares, rejecting the preemption story, given that the preemption motivation would be important only for a firm with market power. Third, using the new specification, we show that a firm with a larger market share earns less from R&D investment, contrary to the view of preemption effect.

3.1 Hypotheses and specifications

The conventional specification (equation (3)) uses the logarithm of the Tobin' q ($q_{i,t} = V(K_{i,t}, IK_{i,t})/K_{i,t}$) as a dependent variable, and uses the logarithm of the value of tangible assets ($\ln K_{i,t}$), the ratio between intangible asset and tangible asset ($(IK/K)_{i,t}$), and the firms' market share ($MS_{i,t}$) as independent variables:

$$\ln q_{i,t} = (\sigma - 1)\ln K_{i,t} + \beta_1 MS_{i,t} + \beta_2 (IK/K)_{i,t} + u_i + \varepsilon_{i,t} \qquad (11)$$

σ is a parameter supposed to indicate the scale economy of production (if there is economy of scale in production, σ exceeds one).The market share is used to measure the profitability of the assets due to the existence of market power. u_i is the unobserved firm-level fixed effect and the $\varepsilon_{i,t}$ is the error term. We generalize this specification, so that it can cover the new specification (see equation (8)) as well.

$$\ln q_{i,t} = (\sigma - 1)\ln K_{i,t} + \beta_1 MS_{i,t} + \beta_2 (IK/K)_{i,t} + \beta_3 IK_{i,t} - 1/2\beta_4 (IK_{i,t})^2 + u_i + \varepsilon_{i,t} \qquad (12)$$

We absorb the price effect of supply expansion(the last term of equation (8)) by the first term of this equation, so that σ in this specification can reflect both economy of scale in production and demand elasticity. If the correct model is the new model, we would find that β_2 is insignificant while β_3 is significant. If the reverse is the case, the conventional model is supported.

Secondly, we estimate the following model based on the conventional model, which is used by Blundell, Griffith and Reenen (1999) to evaluate the preemption effect.

$$\ln q_{i,t} = (\sigma - 1)\ln K_{i,t} + \beta_1 MS_{i,t} + \beta_2 (IK/K)_{i,t} + \beta_5 (MS*IK/K)_{i,t} + u_i + \varepsilon_{i,t} \qquad (13)$$

We allow β_5 to vary across the sub-samples with different level of market shares Since the preemptive motive would be important and would be successful only for the firms with significant market power, we would find that β_5 for the firms with smaller market shares is smaller than that with the largest market shares, if the conventional model is correct. Finally, assuming that the new specification (equation (8)) is a correct model, we estimate the following model to investigate whether a firm with a larger market share in fact earns more from R&D:

$$\ln q_{i,t} = (\sigma - 1)\ln K_{i,t} + \beta_1 MS_{i,t} + \beta_3 IK_{i,t} - 1/2\beta_4 (IK_{i,t})^2 + \beta_6 (MS*IK)_{i,t} + u_i + \varepsilon_{i,t}$$

In particular, if the preemption motivation is significant and is realized, we would find that β_6 is positive and significant.

In estimating these equations, we use fixed effect estimation for the following three reasons (, although we will also report the result of random effect estimation for the purpose of a comparison). First, there are a number of firm specific missing variables (u_i), which are likely to be correlated with independent variables (for an example, a firm with high management capability would be able to undertake more R&D investment). Second, we will use an unbalanced panel for estimation, given that there are a significant number of entries and exits with respect to the stock market. Since only those firms with consistently high market value tend to stay in the stock market, we may have the sample selection bias, unless we remove the firm fixed effect. Third, as pointed out earlier, cross section estimation may significantly reflect the long run relationship between q and the ratio between intangible and tangible assets, so that it can provide a biased-support to the conventional model. In addition to using a fixed effect estimation, we introduce yearly dummies as well as industry by year dummies to control the effects of macroeconomic or industry-wide changes, including the changes in demand growth, technological opportunities and competition on the stock market price.

3.2 Data sources and construction of variables

We have three matched data sources. The financial structure of the firms are from the NEEDS database (Nikkei Electronic Economic Database Systems) which uses mainly the annual financial reports by the firms to the financial regulatory authority of Japan. Information on R&D, advertisement and establishment year as well as the sales of a firm by segments are from the Basic Survey of Business Structure and Activity (Kigyoukatsudou-kihonn-chousa) by the Ministry of Economy, Trade and Industry, which is a compulsory survey. It covers all manufacturing and distribution sectors, as well as some additional sectors. Since the available Surveys were those conducted in 1991FY, 1994FY and every year thereafter up to 2000 FY, we use four data points (1991, 1994, 1997 and 2000 fiscal years). The information on market value of a firm is from the Worldscope database.

The timing of stock market information is chosen so that the stock market fully assimilates the financial and business information of a particular fiscal year. In particular, the market value of a firm as of the end of the following calendar year (mostly 9 months after the closure of the fiscal year) is chosen to correspond to the financial status and business activities of the firm of the fiscal year which mostly end on the March 31st .

We constructed the variables for estimation in the following manner:

(1)Value of tangible asset ($K_{i,t}$): We use the total asset of a firm[iv]. Since most firms do not capitalize R&D and advertisement expenditures, these expenditures and the total asset are non-overlapping separate contributions to the market value of a firm in most cases. Since we use the book values both for the total asset and for the debt of a firm due to our data constraint[v], we introduce the structure of the assets (to be explained next) to control the divergence between the book value and the market value, which is very likely to vary across types of assets.

(2) Structure of the total assets: The variables we use for controlling the divergence between the book value and the market value are the current asset ratio ($ca_{i,t}$=current asset/total asset), the proportion of the financial investments ($inva_{i,t}$=financial investments/total assets), the proportion of land ($land_{i,t}$=land/total assets), and debt asset ratio ($debtasset_{i,t}$). Since the value of land dropped significantly in Japan in 1990s, the proportion of land in the total assets is expected to affect the market value of a firm significantly.

(3) Market value and Tobin's q ($MV_{i,t}$ and $q_{i,t}$): The market value of a firm is defined as the sum of the total market capitalization of a firm as of the end of the

calendar year and the book value of its debt.

(4) Intangible investments ($IK_{i,t}$): We distinguish two types of intangible capital: R&D ($rd_{i,t}$) and advertisement($adv_{i,t}$). R&D of a firm is the sum of the investment internally implemented and that outsourced. Since the length of data available for this study is limited, we use flow value of R&D in stead of stock value. The past studies by Hall (1993a, 1997) suggest that these two measures do not have much difference in explaining the market value of a firm (the flow value often has a higher explanatory power).

(5) Market share ($MS_{i,t}$) : The market is defined at three-digit industry level (59 industries for manufacturing sector and 152 industries for all sectors) and the market share of a firm is defined as the ratio between the sales (domestic and export sales) of each firm and the sum of the sales of all firms covered by the Basic Survey of Business Structure and Activity. Although the Basic Survey is compulsory, it neither covers small firms nor imports. However, since we introduce industry by year dummies as independent variables and use firm-level fixed effect estimation, we can significantly avoid the potential biases due to the incomplete coverage of the survey. When a firm operates in more than one industry, we use a weighted average of its market shares, with its sales in each industry segment as a weight.

(6) Age ($age_{i,t}$): It is the difference between 2002 and the establishment year of a firm. We use this variable as a control variable in random effect estimation.

Our sample is an unbalanced panel, consisting of 2,367 firms, with 102 industry affiliations in total, and covering four years (1991, 1994, 1997, 2000). 1,353 firms belong to the manufacturing sector, with 57 industry affiliations. The summary statistics are provided in Table 1.

(Table 1)

IV. Estimation results

Table 2 shows the results of four estimations based on the general specification covering both conventional and new models (equation (12)). Estimation 1 in the Table shows that the R&D investment as well as its square is highly significant (1% level) while the R&D investment relative to the total asset (relative R&D investment) is insignificant. Thus, the estimation results strongly favor the new model, relative to the conventional model. The significantly negative coefficient of the R&D investment squared suggests a diminishing return on R&D investment on price cost margin. Neither absolute nor relative advertisement investment has a significant coefficient. The coefficient of the tangible capital is negative and significant, although it is relatively small (-0.1).

(Table 2)

Estimation 2 and 3 provide robustness checks. Estimation 2 limits the sample to the manufacturing sector, and Estimation 3 limits the sample to those firms which did R&D for all four years. The estimation results for R&D are highly consistent with that of Estimation 1. The absolute level of R&D investment is highly significant, while its relative level is insignificant. There are two differences. One is higher significance of the advertisement investment relative to the total asset. In these estimations, the relative advertisement expenditure, rather than its absolute level, matters unlike the case of R&D investment. The second difference is that the coefficient of the tangible capital is positive and significant for the consistent performers of R&D (Estimation3).

Estimation 4 provides the results of random effect estimation. We added the logarithm of firm age as another control variable of the firm heterogeneity. In this estimation not only the absolute level of R&D investment but also its relative level is highly significant. This higher significance of the relative R&D investment in random effect estimation, however, is likely to be caused by the correlation between missing variables such as management capability and the relative R&D investment, and by the longrun equilibrium relationship between q and the relative R&D investment.

Let us turn to the estimation results based on the conventional model with the interaction term between R&D and market share (equation (13)). Estimation 5 in Table 3 confirms that the relationship found by Blundell, Griffith and Van Reenen (1999) holds for the Japanese industry too. The interaction term between market share and R&D investment has a highly significantly positive coefficient. Thus, if the conventional model were a true model, this result might be interpreted to show that a firm with a larger market share gains more from R&D investment, which is consistent with preemption effect. However, the next estimation (Estimation 6 in Table 3) shows that the coefficient of the interaction term is significantly larger for the sub-sample of middle share firms or lowest share firms than for the firms with the largest market shares. Thus, the above market power interpretation cannot be supported.

(Table 3)

The positive coefficient of the interaction term as observed in Estimation 5 can be explained easily by the new model, without resorting to preemption effect. Since market share is likely to be nearly proportional to the level of tangible capital of a firm for a given industry, we have the following relationship:

$$MS^{*}IK/K \approx \alpha K^{*}IK/K = \alpha IK \qquad (15)$$

This is nothing but the third term of equation (8). That is, the interaction term is very likely to have simply picked up the effect of R&D investment on price cost margin. The lower coefficient of the interaction term for the firms with the largest market shares is likely reflect the diminishing return of R&D investment on price cost margin.

There is a remaining question of whether the preemption effect holds in the "true" model. Estimation 7 in Table 3 offers an answer. According to the estimation, the interaction term between market share and R&D has a negatively significant coefficient (5% level). That is, a firm with a larger market share has actually a lower marginal return from R&D. Thus, the statistical evidence from market value and R&D investment does not provide support at all to the view that strategic preemption effect is prevalent.

V. Conclusion

This paper may have the following two contributions. First, we have shown that a structural model of market value determination (although a very simple one) implies that the Tobin's q depends on the absolute level of R&D and not on its relative value with respect to the tangible capital. This has hopefully clarified the pitfall in regarding the accounting definitional relationship as a structural equation. Second, we have tested the empirical validity of such structural model. One major implication of this empirical exercise is that the statistical evidence is against the prevalence of preemption effect.

There are a number of research issues to be pursued. One is to understand the difference between R&D and advertisement investments. This paper has shown that R&D follows pretty much the structural model presented, while the advertisement investment does not. Moreover, the relative advertisement investment rather than the absolute investment is significant in some estimations, unlike the case of R&D. This may indicate that advertisement investment is more to do with delivery of knowledge or information to consumers than to do with their creation. The second issue is to explore the inter industry differences of the relationship between intangible investments and market value, given a varying appropriability conditions across industries.

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Appendix 1 Price cost margin and R&D

This appendix illustrates two important channels by which R&D increases the price cost margin of a firm. First, a firm with larger R&D investment is more likely to win the race of drastic innovations. Let us assume that a successful firm has the monopoly price cost margin ($(p_0 - c)/c$) protected by a patent and an unsuccessful firm has a zero margin. The probability of firm j in winning the patent race ($\Pr_j(win)$) depends positively on its level of R&D investment (IK_j) and negatively on the industry aggregate R&D (IK_A), so that the expected price cost margin of firm j is given by

$$E(p_j - c)/c = \Pr_j(win) \times (p_0 - c)/c \qquad \text{(a.1)}$$

$$\Pr_j(win) = \delta_0 + \delta_1 IK_j - 1/2\delta_2 (IK_j)^2 \qquad \text{(a.2)}$$

We absorb the negative effect of industry R&D on the winning probability of firm j by the constant term (δ_0). Thus, the combination of these two equations allows us to get equation (8) in the main text. Note that the price cost margin ($(p_0 - c)/c$) itself may depend positively on R&D investment (IK_j), since larger R&D may enable a firm to acquire a patent with a large scope when it wins. Even if patent protection is not granted, a firm moving quickly in innovation race has the first mover advantage in production. Thus, R&D investment enhances the probability of winning the innovation race and the expected profitability.

The second channel is quality and/or cost advantage due to larger R&D in non-drastic innovation competition. Let us assume that firm j can produce a good with quality z in terms of consumers surplus for marginal cost c, while its competitor produces a good with quality z^* for cost c^*. Bertrand competition forces them to set prices p and p^* in the following manner:

$$z - p = z^* - p^* \qquad \text{(a.3)}$$

If we assume that firm j has a competitive advantage, its competitor is forced to set its price at its cost ($p^* = c^*$). Thus, firm j has the following price cost margin:

$$(p_j - c)/c = \{(z - z^*) + (c^* - c)\}/c \qquad \text{(a.4)}$$

This clearly shows that a firm which improves the quality of its product (z) or reduces its cost (c) by R&D has higher price cost margin. Since quality and cost advantage depends on the level of R&D investment by a firm (IK_j), we can obtain the following expression , similar to equation (8) in the main text.

$$(p_j - c)/c = \beta_0 + \beta_1 IK_j - 1/2\beta_2 (IK_j)^2$$

The above relationship between R&D and price cost margin holds for the other models of competition. Let us consider cost advantage in quantity competition with homogeneous goods (i.e Cournot competition). If we assume constant elasticity market demand curve, it is well-known that the price cost margin of firm j is given by

$$(p - c_j)/p = s_j/\varepsilon, \qquad \text{(a.5)}$$

where ε is the price elasticity of market demand. Since a firm with lower marginal cost of production has a higher market share, it has to have a larger price cost margin. Thus, cost-reducing R&D investment increases price cost margin. In the case of a linear demand, the price cost margin is given by

$$(p - c_j)/p = 1 - (N+1)c_j / \{1 + \sum c_k\}, \qquad \text{(a.6)}$$

where $1-p$ is the market demand and N is the total number of firms. It is immediately clear that a firm with lower cost has a higher price cost margin.

Let us turn to the case of price competition with differentiated products. Higher quality of the product offered by firm *j* makes its reaction curve shift out in the diagram of price competition, since the willingness to pay of its consumers increases. This tends to increase the price of firm j. The opposite move will happen to the reaction curve of the competitor of firm *j*. This tends to reduce the price of firm *j*. Since the first effect is likely to be more important, the firm which is successful in improving its product quality by R&D can increase its price as well as its price cost margin.

[i] See Hall (1999) for a comprehensive review of the literature on the approaches to using market value to assess innovation performance. There are a number of advantages to use market value as the performance measure of R&D. First, it reflects the assessment of the future effects of past and current R&D, unlike accounting profit. Second, it reflects the assessment of the firm by the third parties, while the accounting profit can be adjusted based on the view of the management (see Fisher and McGowan (1983) for the problems of accounting profit).

[ii] Schumpeter (1942) pointed out a number of potential advantages of a large firm or a firm with a large market share in innovation. Low cost of financing, including its ability to pool risk, is one of them. In addition, such firm may have higher ability to appropriate the benefit of R&D. It may also have an advantage due to economy of scale or scope of R&D.

[iii] Generally the longrun profit would depend on entry barriers, although Salinger (1984) finds no significant support to the existence of such longrun entry barriers.

[iv] The total asset of a firm covers financial investments such as equity investments and the value of intellectual property rights purchased.

[v] Hall (1993a,b) and Blundell et al. (1999) report that there is no significant effect due to the difference between the book value and constructed value.

Table 1 Summary statistics（Obs 6966）

Variable	Mean	Std. Dev.	q	lnasset	ms	rd	rda	adv	adva	age	ca	inva	land	debtasset
q	1.215	0.917	1											
lnasset	10.742	1.346	0.022	1										
ms	0.013	0.030	0.045	0.506	1									
rd	0.004	0.023	0.052	0.392	0.323	1								
rda	0.017	0.024	0.069	0.204	0.079	0.372	1							
adv	0.001	0.005	0.070	0.463	0.385	0.606	0.173	1						
adva	0.010	0.022	0.050	0.022	0.032	−0.001	−0.042	0.335	1					
age	51.147	14.210	−0.098	0.252	0.125	0.093	0.115	0.072	−0.135	1				
ca	0.560	0.162	0.021	−0.089	−0.106	−0.047	0.053	−0.124	−0.121	0.006	1			
inva	0.156	0.105	0.005	0.281	0.151	0.151	0.018	0.229	0.167	0.014	−0.486	1		
land	0.091	0.077	−0.071	−0.185	−0.081	−0.099	−0.208	−0.035	0.095	−0.194	−0.516	−0.064	1	
debtasset	0.560	0.204	0.004	0.071	0.033	−0.012	−0.122	−0.040	−0.106	0.177	0.039	−0.097	−0.0374	1

Table 2 Estimation results (I)

Estimation1: Fixed-effects regression				Estimation2:Fixed-effects regression for manufacturing firms				Estimation3：Fixed-effects regression for consistently R&D performing firms				Estimation4: Random-effects regression			
lnq	Coef.	Std. Err.		lnq	Coef.	Std. Err.		lnq	Coef.	Std. Err.		lnq	Coef.	Std. Err.	
lnasset	−0.099	0.016	***	lnasset	0.036	0.023		lnasset	0.060	0.027	**	lnasset	0.000	0.006	
ms	−0.074	0.240		ms	0.486	0.391		ms	−0.176	0.303		ms	0.249	0.197	
rda	−0.190	0.321		rda	0.270	0.338		rda	−0.292	0.410		rda	0.751	0.249	***
rd	5.516	1.037	***	rd	4.545	1.040	***	rd	6.910	1.499	***	rd	3.159	0.747	***
rd2	−7.637	2.592	***	rd2	−5.567	2.578	**	rd2	−6.215	3.194	*	rd2	−5.718	2.078	***
adva	−0.033	0.467		adva	2.742	0.705	***	adva	1.674	0.905	*	adva	0.868	0.284	***
adv	5.895	4.141		adv	−7.357	5.102		adv	−8.660	8.171		adv	1.722	2.613	
adv2	−13.552	46.256		adv2	70.286	50.482		adv2	180.504	117.515		adv2	37.925	35.483	
												lnage	−0.113	0.016	***
1994	−0.167	0.091	*	1994	−0.095	0.281		1994	−0.247	0.295		1994	−0.187	0.091	**
1997	−0.356	0.088	***	1997	−1.153	0.366	***	1997	−0.923	0.279	***	1997	−0.360	0.086	***
2000	−1.119	0.291	***	2000	−0.131	0.251		2000	−0.746	0.389	*	2000	−0.583	0.344	*
Financial structure	Yes			Financial structure	Yes			Financial structure	Yes			Financial structure	Yes		
Industry dummies				Industry dummies				Industry dummies				Industry dummies	Yes		
Industry by year dummies	Yes			Industry by year dummies	Yes			Industry by year dummies	Yes			Industry by year dummies	Yes		
Number of obs = 6966 Number of groups = 2367 R-sq:within = 0.4866 Obs/group: min = 1 between = 0.0187 avg = 2.9 overall = 0.1060 max = 4 F(308,4291) = 13.21				Number of obs = 4326 Number of groups = 1353 R-sq:within = 0.5083 Obs/group: min =1 between = 0.1192 avg = 3.2 overall = 0.2401 max = 4 F(187,2786) = 15.40				Number of obs = 3421 Number of groups = 961 R-sq:within = 0.5153 Obs/group: min = 1 between = 0.1298 avg =3.6 overall = 0.2087 max = 4 F(254,2206) = 9.23				Number of obs = 6964 Number of groups = 2367 R-sq:within = 0.4752 Obs/group: min 1 between = 0.2219 avg = 2.9 overall = 0.3115 max = 4 Wald chi2(411) = 4535.34			
sigma_u | .36415613 sigma_e | .19421891				sigma_u | .31126491 sigma_e | .18575946				sigma_u | .36388534 sigma_e | .19418163				sigma_u | .25992874 sigma_e | .19427914			

***: 1%significant, *:5%signfiicant, *:10% significant

Table 3 Estimation (II)

Estimation 5: Fixed-effects regression				Estimation 6:Fixed-effects regression				Estimation 7 : Fixed-effects regression			
lnq	Coef.	Std. Err.		lnq	Coef.	Std. Err.		lnq	Coef.	Std. Err.	
lnasset	−0.083	0.016	***	lnasset	−0.086	0.016	***	lnasset	−0.098	0.016	***
ms	−0.626	0.280	**	ms	−0.699	0.281	**	ms	0.099	0.254	
rda	0.324	0.307		rda	−0.146	0.345		rd	5.962	0.996	***
msrda	28.786	6.788	***	msrda	29.376	6.821	***	rd2	−6.678	2.458	***
adva	0.500	0.401		msrda: additional effect for middle share firms[Note2]	51.630	26.091	**	msrd	−7.425	3.650	**
				msrda: additional effect for lowest share firms[Note2]	488.939	194.631	**	adv	4.442	3.663	
				adva	0.468	0.401		adv2	11.387	45.069	
1994	−0.188	0.091	**	1994	−0.188	0.091	**	1994	−0.168	0.091	*
1997	−0.373	0.089	***	1997	−0.368	0.088	***	1997	−0.356	0.088	***
2000	−1.135	0.292	***	2000	−1.115	0.292	***	2000	−1.151	0.290	***
Financial structure	Yes			Financial structure	Yes			Financial structure	Yes		
Industry by year dummies	Yes			Industry by time dummies	Yes			Industry by time dummies	Yes		
Number of obs = 6966				Number of obs = 6966				Number of obs = 6966			
Number of groups = 2367				Number of groups = 2367				Number of groups = 2367			
R-sq:within = 0.4813 Obs/group: min = 1				R-sq: within = 0.4824 Obs/group: min =1				R-sq: within = 0.4871Obs/group: min =1			
between = 0.0148 avg = 2.9				between = 0.0144 avg = 2.9				between = 0.0205 avg = 2.9			
overall = 0.0964 max = 4				overall = 0.0938 max = 4				overall = 0.1095max = 4			
F(305,4294) = 13.07				F(307,4292) = 13.03				F(307,4292) = 13.28			
sigma_u | .36399399				sigma_u | .36557271				sigma_u | .36340249			
sigma_e | .19514989				sigma_e | .1949896				sigma_e | .19411073			

Note 1. ***: 1%significant, *:5%signfiicant, *:10% significant
Note 2. Top share firms consist of 202 firms, the middle share firms consist of 1149 firms and the lowest share firms consist of 1140 firms.