Innovation, Market Share, and Firm Value- Patents in Personal Computer Industry

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Abstract

Innovation effects on firm value have not been effectively discussed because previous studies ignore the market structure and tax shields from research and development (R&D) (e.g., Hirschey and Weygandt (1985), Shevlin (1991)). Market structures of personal computer (PC) firms are explored in this paper to the degree to which innovation increases firm value depending on market structure characteristics. Investigating whether firm value is explained by financial statement variable (book value, abnormal return, and tax shields), innovative patent proxies (number of grated patents, inventors, total citations, self-citation, other-citations) and the interaction between market share and patent proxies is the focus of this paper.

R&D tax shields and patent proxies are positively related to market value according to the results of the valuation model. Our investigation additionally shows that sale and patent concentration ratios of the ten largest firms account for more than 67% and 70%, respectively. This implies that dominant firms are more highly involved in innovative activities to maintain market power. The marginal benefit of innovation, according to our findings, becomes greater for firms with stronger market share, which supports the complementary effect of market shares and innovations on firm value. Firms with technological improvement are more valuable through stronger market power.

Keywords: innovation, patent, citation, market structure

1. Introduction

A central question in the R&D management is why market values differ so dramatically across firms having similar book values reported in their balance sheet. Previous studies focus on the research and development (R&D) expenditures to explain such variations (e.g., Hirschey (1982), Hirschey and Weygandt (1985), Culnan (1986), Cockburn and Griliches (1988), Kotabe (1990), Shevlin (1991), Hitt, Hoskisson, and Kim (1997), Chan, Lakonishok, and Sougiannis (2001), Kotabe, Srinivasan and Aulakh (2002), Shi (2003)). They concentrated on demonstrating that R&D expenditure is an intangible asset and investigated the relationship between market values and R&D expenditures. However, how R&D investments expand firm value through (1) technological innovations, (2) complementary effect of market power, and (3) tax shields derived from R&D expenditures is not well discussed in prior research. To provide complete evidence about innovative contributions to firm value, this paper investigates innovative impact on firm value in these threefold.

As for technological innovation, this article selects patent bibliographic and citation information to measure technological innovation. Most studies examine the relationship between R&D spending and firm value. However, R&D expenditure is an input of technological innovations, rather than an output, and is often allocated in a somewhat arbitrary fashion in firm counts. Since R&D spending contains probability of failure in inventions, the risk or uncertainty leads to the biased measurement of innovations and the conflicting findings regarding insignificant or negative associations between firm value and R&D spending (e.g. Newman (1968) and Fung (2003)). R&D spending does not represent technological innovation well. To avoid the bias measurement problem, this article selects patent bibliographic and citation information to measure technological innovation in quantity and quality as proposed by Griliches (1981), Cockburn and Griliches (1988), Griliches (1984), Hall, Jaffe and Trajtenberg (2005). Because patent must be a newly skilled practitioner of relevant technology, it is tangible indicator of technological improvements to explain how R&D achievements enlarge firm values.

As for market power, this paper effectively discusses the degrees to which innovation increases firm value as conditioned by market structure characteristics. Prior research suggests the complementary relations between innovations and market shares. These studies emphasize the firm's profits from market power through technological barriers. Firms with the capability of technology innovation contain valuable resources that are hard to imitate and difficult to substitute for, so they are potential to keep the leading positions, especially for the competitive technology industries (e.g., Porter (1990), D'Aveni (1994), Hamel and Prahalad (1994), Schilling and Hill (1998), Grant (1991)). Schumpeter (1970) and Reinganum (1981) strongly proposed that firms with a large market share in a product market were presumably better off exploiting the technology to maintain their dominate advantages. In the Gibert and Newbery (1982) auction model, R&D incumbent monopolists have greater incentives to search for innovations than potential entrants because the monopolist tends to innovate more to increase entry barriers and the industry evolution will be characterized by persistent dominance. The marginal benefit of an innovation (an additional increment to the firm's innovation) will be more valuable to a leader with high market share than a follower with low market share, as concluded by Blundell, Griffith and Reenen (1999). Their findings suggest that innovation expands firm value not only by technological improvement but by the complementary effect of market structure. Thus, this paper sheds light on innovative incentive for firms with different market share levels. We further model the innovation as the function of market share and explores the greater marginal benefit of innovation for the leading firms. In addition to the market structure criteria, company's sales divided by total industry sales, used in previous studies such as Blundell, Griffith, and Reenen (1999), this study also collects unique data about market structure of specific products from the IDC database. We intend to confirm that core technological improvements strengthen market shares not only for the specific products but for the firm.

Furthermore, this paper makes contribution from the consideration of the tax shield effect on firm value as proposed by Sougiannis (1994). Since R&D expenditures reduce net income, leading to another economic consequence of tax savings under current accounting and tax regulations, tax shields are crucial in technology decisions. As Scholes and Wolfson (1992) point out, the price of tax-favored investments increase by the present value of tax savings, making tax savings value-relevant. In their inferences, tax shields are critical in technological strategies, especially for high-tech firms with large amount of R&D expenditures. If our model, which explains the innovative impact on firm value, lacks the tax shield factors, the models may omit important variables and face the endogeneity problems. Thus, this paper adds tax shield factor in valuation models to provide a consistent estimate of the parameter.

As the extensions of previous studies, investigating the impact of (1) technological innovations, (2) market power, and (3) tax shields derived from R&D expenditures on firm value expansion is the main purpose of our study. This paper focuses on the personal computer (PC) industry because technological innovation plays an important role in the competitive PC industries. Esposito and Mastroianni (2002) indicated that the PC was considered a product primarily capable of memorizing and processing data in 1980s, but has altered to take on a multimedia function since 1990. Innovations play important roles for PC firms because they have to develop new functions to satisfy consumer needs in varying environments. PC industry is suitable for us to examine the R&D impact on firm values. Based on the Olson model, the firm value is explained through financial statement variables (book value and abnormal return), technological innovation variables (number of granted patents, inventors, total citations, self-citation and other-citations), tax shield factors and the complementary effect between market share and patent proxies.

The results of Olson's valuation model exhibit that both patent number and patent citation indicators are positively related to firm values, which suggests that the value creations depend on technological improvements not only in quantities, but also in qualities. Also, the tax shields are significantly positive in valuation model, which verifies the critical role of tax shield in technology management. As for the complementarities between technological innovation and market structure, the positive associations between technological achievements and market shares convincingly support that dominant firms seek greater participation in innovative activities. This confirms that firms with technological improvement are inclined to be more valuable through stronger market power, which also explains why leading firms are more involved in technological innovations.

The remainder of the paper is organized as follows: Section 2 provides a theoretical framework for the valuation model and hypothesis development. Section 3 describes the data and sample used in the paper. Section 4 provides a detailed discussion of methodology. Section 5 presents the empirical results. A conclusion is given in Section 6.

2. Theoretical framework in valuation model and hypothesis development

2.1 Introduction of R&D tax shields

Under current accounting standards, R&D expenditures should be recognized as expenses, so reported accounting earnings should be written as:

$$X_t = (X_t^B - RD_t)(1-\tau_t) = X_t^B(1-\tau_t) - RD_t + RD_t\tau_t \qquad \text{(i)}$$

where X_t is after-tax earnings at time t; X_t^B is earnings before expensing R&D expenditures at time t; RD_t is R&D expenditures at time t; and τ_t is the firm's tax rate at time t. The equation (i) suggests reported earnings are composed of three terms. The first term is equal to after-tax earnings before expensing R&D expenditures. The second term is the deductions of R&D expenditures in reported earnings according to the accounting standards. The third term is the tax shields $RD_t\tau_t$ induced by R&D expenditures. Because firms deduct R&D expenses RD_t from reported earnings, their total tax savings are $RD_t\tau_t$. In other words, R&D expenses cause less cash outflow by tax shields $RD_t\tau_t$. Firms have tax shields when they recognize R&D expenses.

If the firm does not recognize any R&D expenses, namely, $RD_t = 0$, reported accounting earnings may be rewritten as:

$$X_t = X_t^B(1-\tau_t) \qquad \text{(ii)}$$

Comparing equation (i) with equation (ii), we find that firms without R&D expenses cannot share tax shields derived from R&D expense recognition. Tax shields are an important economic consequence under the current expensing policy of R&D expenditures.

2.2 Valuation model

To explore the impact of innovation on market values, this article utilizes an accounting-based asset valuation model developed by Ohlson (1995). Ohlson (1995) demonstrates that the clean surplus equation represents a firm's market value as a function of book value of equity and earnings. He allows the presence of other value-relevant variables in the valuation function, so this paper can add the value-relevant innovation variables, which are not recognized as book value or earnings in financial statements, under Ohlson framework as follows:

$$P_t = Y_t + \alpha[X_t - rY_{t-1}] + \gamma Z_t \qquad \text{(iii)}$$

where P_t is the market value of the firm's stock at time t; Y_t is the book value of the firm's stock at time t; X_t is reported earnings at time t; r is the risk free interest rate; $\left[X_t - rY_{t-1}\right]$ is defined by Ohlson as abnormal earnings. Z_t is the other value-relevant variables at time t; and α, γ are valuation parameters. As the arguments that innovations promote firm value as mentioned above, the technological innovation should be attributed to the other value-relevant variables Z_t in Ohlson models. Equation (iii) implies that market value equals the book value adjusted for abnormal earnings and innovation. If abnormal earnings and book values are sufficient to evaluate the firm, then $\gamma = 0$. Otherwise, the innovation provides incremental information on firm value, $\gamma \neq 0$.

If we substitute the reported earnings X_t with the three components in the right-side of equation (i), we can rewrite equation (iii) as equation (iv):

$$P_t = Y_t + \beta_1[X_t^B(1-\tau_t) - rY_{t-1} - RD_t] + \beta_2[RD_t\tau_t] + \beta_3 Z_t \qquad \text{(iv)}$$

Based on Ohlson's valuation model, equation (iv) disaggregates R&D tax shields from earnings to control tax shield factors. Equation (iv) suggests that market value is explained by these components: (1) book value Y_t, (2) abnormal returns before R&D tax shields $\left[X_t^B(1-\tau_t) - rY_{t-1} - RD_t\right]$, (3) tax shields $RD_t\tau_t$ derived from R&D expenses, and (4) value-relevant innovation variable Z_t. Because patent must be a skilled practitioner of relevant technology, it is suitable to use the granted patent indicators as criteria of innovation variable Z_t. If patent indicators have positive effects on firm value prediction, then $\beta_3 > 0$, otherwise, $\beta_3 = 0$. The analysis leads to the following hypothesis:

H_1: The greater the number of patent indicators a firm has, the more likely it is to become valuable.

According to the complementary relations between market shares and innovations, we further model the innovation as a positive function of market share as equations (v):

$$Z_t = \delta_0 + \delta_1 \times S_t \qquad \text{(v)}$$

where S_t is the market share at time t. Since technological innovation increases for firms with higher market shares, the slope of the market share coefficient should be positive, ie. $\delta_1 > 0$. The analysis leads to the following hypothesis:

H_2: Firms with greater market share are more likely to be involved in technological innovations.

If this is the case, we would expect innovations to be more highly valued for leading firms. We model the innovation variable Z_t as a function of market share in equation (v) and allow for the interaction between market share and innovations, so we can rewrite equations (vi) as follows:

$$P_t = Y_t + \beta_1[X_t^B(1-\tau_t) - rY_{t-1} - RD_t] + \beta_2[RD_t\tau_t] + \delta_0 Z_t + \delta_1(Z_t \times S_t) \qquad \text{(vi)}$$

In equation (vi), the interaction between firm's market share and innovation variable, ($Z_t \times S_t$), is the key strategic variable used to examine the hypothesis that dominant firms profit more from innovations than other firms. If high market share firms gain a higher return from innovative activities, the complementary relation between market share and innovation will be reflected in a positive value of δ_1. The positive coefficient $\delta_1 > 0$ implies that marginal innovative impact on firm value $\frac{\partial P_{,t}}{\partial Z_t}$ is positively associated with market share S_t as following hypothesis:

H_3: Market share is positively related to the marginal innovative effect of firm value.

3. Data and sample

This paper focuses on personal computer (PC) technology, which is generally considered to be an excellent example of a growing and innovative industry. Because this paper intends to precisely measure the market share in specific PC product, we choose firms which are classified as PC industry in the IDC database or whose GICS sub-industry code equals to 45202010 to investigate the effect of core technology in PC products on PC market share and firm values. We apply firm level data including market share, financial and innovative variables to explain market value in 2002 for our sample firms. With financial data about the research variables available for us, our criterion results in forty firms for our sample.

For market share variables, we gain the PC shipment value for the ten largest firms from the IDC database, in which PC products contain server, desktop, and portable computer. For financial variables, we obtain market value, book value, earnings, tax rate, R&D spending, sales revenue and risk free interest rate for each firm from the Compustat database.

For innovative variables, this paper chooses the counts and citations of patents registered at the U.S. Patent Office. Because unit shipment to U.S. accounts for more than 30% of the worldwide PC market[1] and U.S. is a leading technology country in information technology industry, foreign PC firms prefer to register their patents in the U.S., believing U.S. legal systems are efficient enough to protect their patents. In addition, the U.S. patent database[2] provides us complete data about the patent citation and bibliographic information, so this paper uses the U.S. patent data for innovative proxies.

By working closely with innovation in this field, we decide to use specific keywords techniques in Kurokawa, Tong-Ngok and Yamada (2002). Since only patents of core technology can create firm value, it is proper for this study to focus on the patents which represent the core technology in PC fields. Thus, this paper collects the patents whose International Patent Classification (IPC) codes belong to G06F (IPC=G06F), namely, the patents attributed to the technology in computing, calculating and counting. In addition, we select the patent with the following keywords: ((desktop or server or portable) and computer) as this paper focuses on the specific products: desktop, server and portable computer.

Hall, Jaffe, and Trajtenberg (2005) propose that patents depreciate over time, and that the patent granted much earlier is out-of-date without value-addition for firms. To evaluate patent impact on firm value in 2002, we exclude patents granted before 1994 as they are of no value in 2002. On the other hand, Hall and Trajtenberg (2004) suggest the patent citation lags and application-grant lags. In addition, the application-

[1] The quarterly unit shipment of the U.S. market accounts for 32.36%, 33.44%, 34.95%, 35.97%, 32.22%, 33.04%, and 33.21% of the worldwide market from 2003 to the third quarter in 2004 according to the IDC database.

[2] USPTO website: www.uspto.gov

grant lag time in our sample is about two years. It is suitable to postpone the patent grant and citation time. Thus, the patent citation and bibliographic information ranges from 1994 to 2004 in our research because innovation during this period is technologically significant and commercially important for firm value in 2002. The citation number of each firm is collected by the patent number with the key words ((server or desktop or portable) and computer) from 1994 to 2004.

4. Methodology

4.1 Regression test

This paper examines associations between technological innovations and firm values by regression based on equation (iv). Previous research such as Griliches (1981) and Shevlin (1991) fail to account for the tax shield factor, which might create a specification error and bias the estimates of the innovative impact on firm values. Thus, this study revises the models and controls the tax saving factors. In addition, this study examines the value-relevance of technological improvements on firm values. If technological innovation does not provide information on market value, book value and abnormal earnings will reflect market value, namely, $\gamma = 0$ in equation (iv). The valuation regression is as follows:

$$P_{i,t} = Y_{i,t} + \varphi_1 [X^B_{i,t}(1-\tau_{i,t}) - rY_{i,t-1} - RD_{i,t}] + \varphi_2 [RD_{i,t}\tau_{i,t}] \qquad (1)$$

where $P_{i,t}$, $Y_{i,t}$, r, $X^B_{i,t}$, $RD_{i,t}$, $\tau_{i,t}$ is the market value, book value; risk free interest rate, earnings before expensing R&D expenditures, R&D expenditures, and tax rate for the ith firm at time t, respectively. $RD_{i,t}\tau_{i,t}$ represents the tax shield induced by R&D expenditures. This equation controls the tax shield factor of R&D expenditures to avoid biased estimation.

In the article, we emphasize innovative activity effect on market value. Equation (iv) based on Ohlson’s valuation model provides us a more general form to examine the interrelationship between market value and technological innovations. Mansfield (1986) as well as Archibugi and Pianta (1996) indicated that most patentable inventions were patented practically. Besides, prior research has also long used patent data in analysis of technological improvement (e.g., Griliches (1981), Griliches (1984), Hall, Jaffe and Trajtenberg (2005)), so this article selects the granted patent indicators Z_{ki} as criteria for technological innovations. The regression is as equation (2):

$$P_{i,t} = Y_{i,t} + \psi_{1k}[X^{B}_{i,t}(1-\tau_{i,t}) - rY_{i,t-1} - RD_{i,t}] + \psi_{2k}[RD_{i,t}\tau_{i,t}] + \omega_k Z_{ki} \quad (2)$$

where Z_{Ki} represents five innovative indicator--total number of granted patents PN_i, total number of patent inventors INV_i, total number of patent citations CIT_i, total number of patents cited by other patents $OCIT_i$, total number of patent self-citations $SCIT_i$, respectively, for the ith firm.

In equation (2), we choose patent number PN_i or inventor number INV_i as the innovation activity proxies. In addition to these two quantity criteria, we also shed qualitative light on innovations. Since patent citations can be seen as direct observations of technological impact and knowledge spillovers, this article selects patent citation number CIT_i, self-citation number $SCIT_i$, and other-citation number $OCIT_i$ as well. This paper examines whether firms with more innovative contributions are inclined to be valuable. We use t-statistics to examine the null hypothesis $H_1 : \omega_k = 0$. Because the five patent proxies are highly correlated, we examine the innovative effect with the proxies individually to avoid the collinear problem.

To examine whether "innovation proxies" have incremental explanatory power with regard to market value, we use partial F statistics (Greene, 1993, pp. 337-338) and likelihood ratio (LR) statistics (Greene, 1993, pp. 159-162). The partial F statistics test is the same as the test in Kotabe, Srinivasan and Aulakh (2002). It compares the sum of the square residuals between equations (1) and (2):

$$\text{F(J, N-K)} = \frac{(\text{R}^2\text{-R}_*^2)/\text{J}}{(1\text{-R}^2)/(\text{N-K})} \quad (3)$$

where:

R^2 =Sum of the square residuals for the model with incremental patent predictors (equation (2))

R_*^2 =Sum of the square residuals for the model without patent predictors (equation (1))

J= Number of the incremental patent predictor

N= Number of observations in the sample

K=Number of predictors in the model with incremental patent predictors

The LR statistics tests the difference in the log-likelihood function between equations (1) and (2). If L and L_* are the likelihood function evaluated by equations with and without incremental patent predictors, respectively, the likelihood ratio (LR) statistics is calculated as follows:

Likelihood ratio (LR) statistics= $-2\ln\frac{L_*}{L} \sim \chi^2(J)$ (4)

4.2 Degree of concentration and the correlation test

The section primarily focuses on the market structure and innovative conditions surrounding the ten largest firms because these firms occupy the most of the worldwide market. This paper examines whether most innovations occur in leading firms by comparing the degree of concentration between innovations and sales. First, we calculate seller concentration ratios for the analysis of market structure. Seller concentration is the proportion of shipment values that accounts for the ten largest firms as equation (5):

$$CRS_{10} = \sum_{i=1}^{10} S_i \quad (5)$$

where:

CRS_{10} : Concentration ratio of sales for firms with top ten shipment values

$S_{i,t}$: Shipment value for the ith firm deflated by total worldwide shipment value at time t (%)

The concentration ratio of the ten largest firms CRS_{10} represents the market share for dominant PC firms. Using the concentration ratio, we can measure the monopoly power of the dominant PC firms. Second, this paper tests the degree of concentration in technological innovations for the ten largest PC firms as equations (6), (7), (8), (9), (10):

$$CRPN_{10} = \sum_{i=1}^{10} PN_i \Big/ \sum_{j=1}^{N} PN_j \quad (6)$$

$$CRINV_{10} = \sum_{i=1}^{10} INV_i \Big/ \sum_{j=1}^{N} INV_j \qquad (7)$$

$$CRCIT_{10} = \sum_{i=1}^{10} CIT_i \Big/ \sum_{j=1}^{N} CIT_j \qquad (8)$$

$$CROCIT_{10} = \sum_{i=1}^{10} OCIT_i \Big/ \sum_{j=1}^{N} OCIT_j \qquad (9)$$

$$CRSCIT_{10} = \sum_{i=1}^{10} SCIT_i \Big/ \sum_{j=1}^{N} SCIT_j \qquad (10)$$

where N is number of observations in the sample. $CRPN_{10}$, $CRINV_{10}$, $CRCIT_{10}$, $CROCIT_{10}$ and $CRSCIT_{10}$ are concentration ratios of patent number, inventor number, patent citations, other citations and self-citations , respectively, for the ten largest firms. We examine the association between the market share and patent indicators for the ten largest firms. Because the sample is small, we select the nonparametric method- Shearman's rank correlation coefficient to test the associations. For robust checks, this paper also examines the Pearson correlation coefficients. By the correlation test, this paper explores whether firms with technological advantages contain a larger percentage of market shares.

4.3 ANOVA test

To test the hypothesis H_2, this paper examines the difference in innovative activities between firms with different market share levels. This paper selects firms with the ten largest market shares as the High sub-sample and the other firms as the Low sub-sample. Two criteria are chosen to measure market share in 2002. As Blunndell, Griffith and Reenen (1999), we select the company's sales divided by the total sales in our sample firms. The other indicator of market share is the company's shipment value divided by worldwide shipment value. Then, we perform analysis of variance, ANOVA, to investigate the difference in technological innovation between High and Low sub-samples. We use F statistics to compare the difference of the patent indicators between the two sub-samples. By concentration ratios, correlation tests and ANOVA tests, we can obtain the complete evidence as to whether market share is positively related to firm's innovations.

4.4 Tests of the complementary relation between market share and innovations

Since market share influences the innovative benefit on firm value in equation (vi), this paper further examines the complementary relation between market share and innovation. If we model the innovation variable as a function of market share and allow for the interaction between market share and patent indicators in our model, we can rewrite the regressions as equation (11):

$$P_{i,t} = Y_{i,t} + \lambda_{1k}[X_{i,t}^{B}(1-\tau_{i,t}) - rY_{i,t-1} - RD_{i,t}] + \lambda_{2k}[RD_{i,t}\tau_{i,t}] + \ell_{k} Z_{ki} + \theta_{k}(Z_{ki} \times S_{i,t}) \quad (11)$$

This paper selects two criteria to measure market share $S_{i,t}$ in 2002. As Blunndell, Griffith and Reenen (1999), we select the company's sales for ith firms divided by the total sales in our sample firms. The other criteria for $S_{i,t}$ is the ith firm's shipment value divided by worldwide shipment values for the ten largest firms and zero for the other firms. The proportion of the shipment values for the ten largest firms range from 1.87% to 18.15%, so market share is less than 1.87% for the other firms. We estimate the market share of the other firms as zero since we lack the data. In equation (11), we test the hypothesis $H_3 : \theta_k > 0$ to investigate the interaction impact of market share and technological innovation on firm value. To compare the explanatory power between equations (1) and (11), this paper uses partial F statistics (equation (3)) and likelihood ratio (LR) statistics (equation (4)). By partial F statistics and likelihood ratio (LR) statistics, we can ensure that innovations (Z_{ki}) and interaction effects ($Z_{ki} \times S_{i,t}$) provide significant information content on firm value.

5. Empirical results

5.1 Results of innovative impact on firm value

In order to test the above hypotheses, we chose the PC technology which is considered to be an excellent example of a growing and innovative industry. Figure 1 exhibits that worldwide total units of shipment increased from 19,987,644 to 30,877,648 from 1999 to 2002, while the worldwide total value of shipment by vendor decreased from 223,178 to 172,911 million U.S. dollars. Although PC demands have substantially increased in recent years, shipment values decreased due to technology improvements and cost efficiency. In addition, the PC becomes a product capable of not only memorizing and processing data, but also executing several multimedia functions. It becomes more important for PC firms to develop technological innovations to satisfy consumer needs and maintain market share.

[Insert Figure 1 about here]

Descriptive statistics of variables and the estimation of equations (1) and (2) are shown in panel A and panel B of table 1, respectively. In both equations (1) and (2), the earnings valuation parameter is positive and highly significant. This indicates that the market capitalizes on earnings in determining market values. As predicted, the R&D tax shield valuation parameter is significantly positive at the 5% level. The R&D tax shields increase market value due to tax savings from the expensing of R&D. It implies that the expensing of R&D gives rise to tax savings and increases firm values. With respect to patent indicators, all are significantly and positively associated with firm value. Consistent with hypothesis H_1, firms with more granted patents, inventors, and patent citations are inclined to have greater market value.

[Insert Table 1 about here]

To examine the incremental explanatory power of patent indicators, we initially compare the adjusted R^2 between equations (1) and (2). The adjusted R^2 of equation (2) for all patent indicators is more than 94.6%, higher than that of equation (1), 92.78%. The innovative proxies provide incremental information content of firm value. Besides, results of LR statistics and partial F statistics reject the hypothesis $H_1 : \omega_k = 0$. Patent indicators significantly and additionally explain the variations of market values. The results imply that investors may evaluate companies according to innovative capacities for each firm, and patent indicators are good criteria of technology innovations.

5.2 Results of concentration ratio and correlation test

The section primarily focuses on the market structure and innovative conditions surrounding the ten largest firms because these firms dominate the worldwide PC market. The ten largest firms account for 67.86% of PC market share, which suggest that leading firms dominate the PC industry. In particular, more than 40% of the market share concentrates on the four largest firms. Shipment values of the four largest firms in 2002 range from 10,037 to 31,381 million U.S. dollars and the market shares range from 5.80% to 18.15%. Because the concentration ratio for the four largest firms is up to 49.12% ($CRS_4 = \sum_{i=1}^{4} S_i = 0.4912$), the market structure of PC industry should be classified as "loose oligopoly competition" in which firms fail to collude.

Table 2 provides the results of concentration ratio of sales and innovations for firms with the top ten worldwide shipment values. Panel A of table 2 shows that PC sales of firms with the top ten shipment values range from 117,342 to 152,098 million U.S. dollars during 1999-2002. Seller concentration ratios for the ten largest firms are up to 67%. This means that the main PC firms have long dominated the sale of PC products and that small PC firms account for a trivial market share.

[Insert Table 2 about here]

The patent concentration ratio of the ten largest firms is shown in Panel B of table 2. For all the indicators, concentration ratios of patent indicators account for more than 70% for firms with the top ten shipment values, which perform higher than the seller concentration ratio. It implies that the largest firms dominate the market share and technological innovation in the PC industry. Dominant PC firms develop the core technology of PC production. This agrees with the findings of Mahmood and Mitchell (2004) that firms increase innovations when entry barriers are not too weak or too strong. PC firms with a stronger market share contain greater R&D achievements since the entry barrier of loose oligopoly PC industry is at the intermediate level.

By using the nonparametric method- Shearman's rank correlation coefficient, this paper investigates the association between market share and patent indicators for PC firms with the top ten shipment values. Panel A of table 3 exhibits that Shearman's rank correlation coefficients range from 51.7% to 77% between patent indicators and market share ratios. For robust checks, panel B of table 3 exhibits that the Pearson correlation coefficients are more than 30%. Obviously, the results reveal that market share is positively related to technology innovation. Firms with stronger innovative capacity have competition advantage and market power measured by seller concentration, which correlates with the inference of Schumpeter (1970) and Reinganum (1981).

[Insert Table 3 about here]

5.3 Results of ANOVA test

The results of the analysis of variance, ANOVA, are shown in table 4, in which the market share criteria are the company's sales divided by the total sales and the company's shipment values divided by total shipment values in panel A and panel B, respectively. We use F statistics to compare the difference of the patent indicators between the High and Low market share sub-samples. The results reveal that firms in High sub-sample have more granted patents, inventors, and citations than those in Low sub-sample. In panel A, the results of the F statistics exhibits the differences in the five patent indicators are all statistically significant at 0.01 confidence level. In panel B, the results of the F statistics exhibits the differences in the number of self-citations, other patent citations, total citations, granted patents, and patent inventors are statistically significant at 0.1, 0.01, 0.05, 0.01 and 0.01 confidence level, respectively. This means that firms with technological progressiveness have competition advantage and contain greater market power than non-innovators, consistent with the hypothesis H_2. The results of correlation tests and ANOVA tests indicate that technological innovation is the key determinant of market structure.

[Insert Table 4 about here]

5.4 Results of complementary relations between innovation and market share

Equation (2) is a general equation derived for isolating the impact of market share on firm performance. Equation (11) gives the impact of market share on marginal benefit of innovations. Table 5 exhibit the results of the equation (11), in which the market variable $S_{i,t}$ is the company's sales divided by the total sales and the company's shipment values divided by total shipment values in panel A and panel B, respectively. In panel A, the coefficients of patent variables Z_{ki} and the interaction variables $(S_{i,t} \times Z_{ki})$ are significantly positive for all the patent indicators. In panel B, the coefficients of patent variables Z_{ki} and the interaction variables $(S_{i,t} \times Z_{ki})$ are significantly positive for the patent number PN_i, total patent citation CIT_i, and other patent citation $OCIT_i$. The positive coefficients ($\theta_k > 0$) support that marginal innovative impact on firm value $\frac{\partial Y_{i,t}}{\partial Z_{ki}}$ is positively associated with market share $S_{i,t}$. Consistent with hypothesis H_3, the results confirm the complementary relations between innovation and market share. The marginal benefit of an innovation will be more valuable to a leader with high market share than a follower with low market share. The findings in equation (11) explain why dominant firms are more involved in innovations mentioned in 5.3 because technological improvement can promote firm value through stronger market power.

[Insert Table 5 about here]

To examine the incremental explanatory power of patent indicators Z_{ki} and interaction effect $(S_{i,t} \times Z_{ki})$, we initially compare the adjusted R^2 between equations (1) and (11). The adjusted R^2 of equation (11) is more than 94.8%, higher than that of equation (1), 92.78%. The innovative and interaction proxies provide incremental information content of firm value. Besides, the results of LR statistics and partial F statistics also suggest that the patent and interaction indicators significantly and additionally explain the variations of market values.

6. Conclusions

This research aims to analyze the influence of patents, market share, and tax shields from R&D expenses to the degree in which technological innovation increases firm value in the PC field. The results exhibits that business valuation depends on technological improvements since competency indicator such as patents, patent citations, and patent inventors are influential in market value. Besides, the sale and patent concentration ratios of the ten largest firms account for more than 67% and

70%, respectively. It suggests that dominant firms concentrate on the most important innovations within the core technology of the PC industry. Particularly, we further find that marginal innovative effect is significantly positive related to firm value. The degrees to which innovations expand market shares explain how innovations increase firm value.

Figure 1
Worldwide PC total shipment values and units by vendors

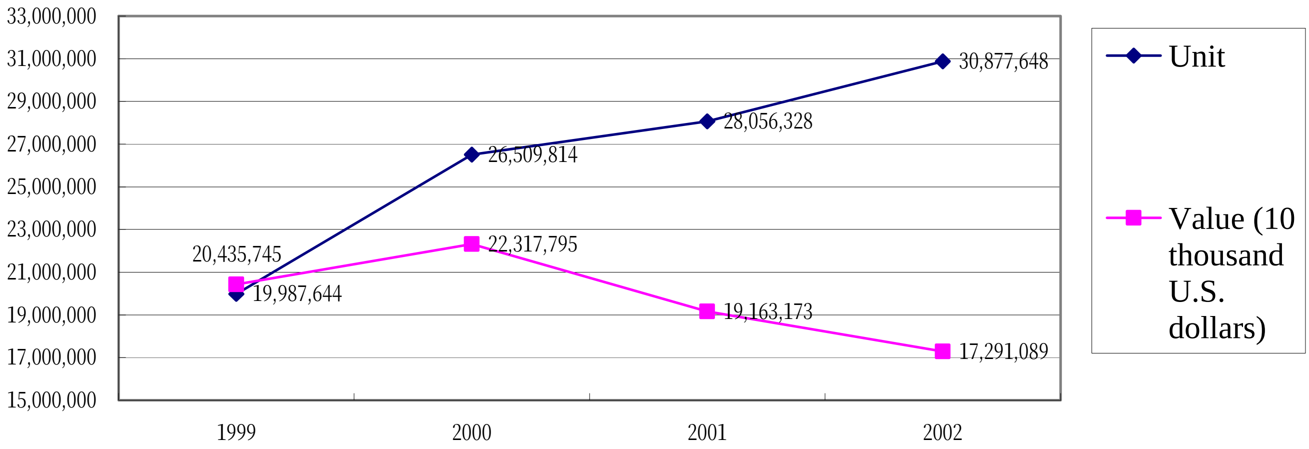

Table 1 Results of innovative impact on market value

Panel A: Descriptive statistics of variables

	Market Value[a]	Book Value[b]	Tax Shield[c]	Abnormal Return[d]	Patent Number	Inventor Number	Total Citation	Other Citation	Self Citation
Mean	8,051	3,141	245	-19	28	54	38	32	6
Maximum	133,547	36,262	249	3,569	541	1,166	677	536	141
Minimum	6	-759	-114	-2,536	0	0	0	0	0
Standard Deviation	23,515	7,228	595	969	88	187	120	95	25

([a,b,c,d] million U.S. dollar)

[C] Tax shield $RD_{i,t}\tau_{i,t}$ is the product of tax rate and R&D expenditures. Tax rate $\tau_{i,t}$ is calculated using COMPUSTAT data as follows:

$$\frac{total\ tax\ \exp ense - deferred\ tax\ \exp ense}{pretax\ book\ income - \dfrac{deferred\ tax\ \exp ense}{statutory\ m\arg inal\ tax\ rate}}$$

If the deferred tax expense is greater than total tax expense, the tax rate may be negative and firms defer the tax shields to next periods.

[d] $abnormal\ return = X^{B}_{i,t}(1-\tau_{i,t}) - rY_{i,t-1} - RD_{i,t}$

Panel B: Results of regressions

$$P_{i,t} = Y_{i,t} + \varphi_1[X^{B}_{i,t}(1-\tau_{i,t}) - rY_{i,t-1} - RD_{i,t}] + \varphi_2[RD_{i,t}\tau_{i,t}] \quad (1)$$

$$P_{i,t} = Y_{i,t} + \psi_{1k}[X^{B}_{i,t}(1-\tau_{i,t}) - rY_{i,t-1} - RD_{i,t}] + \psi_{2k}[RD_{i,t}\tau_{i,t}] + \omega_k Z_{ki} \quad (2)$$

	Equation (1)	Equation (2)				
Patent (Z_{ki})		PN_i	INV_i	CIT_i	$SCIT_i$	$OCIT_i$
Z_{ki}		0.0861 (4.6075)***	0.0379 (3.7045)***	0.0520 (4.8614)***	0.2030 (3.8948)***	0.0681 (5.1027)***
$Y_{i,t}$	1.4382 (9.0135)***	0.9863 (6.1265)***	1.0497 (6.0802)***	1.1402 (8.1884)***	1.2320 (8.4874)***	1.1170 (8.1081)***
Abnormal return[a]	18.6565 (16.2050)***	13.4712 (9.2626)***	13.4163 (7.7714)***	14.7173 (12.1371)***	15.4347 (12.0696)***	14.5770 (12.2289)***
$RD_{i,t}\tau_{i,t}$	19.3860 (9.2638)***	13.7351 (6.6175)***	13.9100 (5.9744)***	14.8728 (7.8930)***	15.5201 (7.6392)***	14.7707 (8.0094)***
Constant	1.1365 (1.0158)	0.8577 (0.9559)	0.9808 (1.0189)	0.6883 (0.7808)	1.0816 (1.1411)	0.5678 (0.6553)
R^2	0.9334	0.9585	0.9521	0.9602	0.9535	0.9618
Adjusted R^2	0.9278	0.9538	0.9467	0.9557	0.9482	0.9574
Partial F		10.9933***	7.1650**	12.2098***	7.9200***	13.4563***
LR		18.9634***	13.2322***	20.6384***	14.4026***	22.2458***

*Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Table 2 Results of concentration ratio

Panel A:

Concentration ratio of market share for the ten largest firms

	1999	2000	2001	2002
Shipment value-Top 10	140,129.83	152,098.33	129,068.21	117,342.36
Shipment value-Others	64,227.71	71,079.75	62,563.27	55,568.48
Concentration Ratio- Top10	68.57%	68.15%	67.35%	67.86%

Panel B:

Concentration ratio of patent indicators for the ten largest firms

	$CRSCIT_{10}$	$CROCIT_{10}$	$CRCIT_{10}$	$CRPN_{10}$	$CRINV_{10}$
Shipment value-Top10	193.00	1105.00	1298.00	986.00	1928.00
Shipment value- Others	81.00	416.00	497.00	256.00	429.00
Concentration Ratio- Top10	70.43%	72.65%	72.31%	79.39%	81.80%

Table 3 Results of correlation test

Panel A: Results of Shearman's rank correlation test

	S_i	$SCIT_i$	$OCIT_i$	CIT_i	PN_i
$SCIT_i$	0.517				
$OCIT_i$	0.697	0.886			
CIT_i	0.669	0.914	0.997		
PN_i	0.770	0.868	0.842	0.851	
INV_i	0.539	0.886	0.697	0.717	0.867

Panel B: Results of Pearson correlation test

	S_i	$SCIT_i$	$OCIT_i$	CIT_i	PN_i
$SCIT_i$	0.289				
$OCIT_i$	0.511	0.954			
CIT_i	0.470	0.971	0.998		
PN_i	0.395	0.989	0.984	0.992	
INV_i	0.343	0.996	0.972	0.984	0.995

Table 4 Results of ANOVA test

Panel A: Market share indicator is the company’s sale divided by total sales.

	F statistics	P-value
$SCIT_i$	7.45	0.009***
$OCIT_i$	12.76	0.001***
CIT_i	11.53	0.002***
PN_i	11.04	0.002***
INV_i	9.36	0.004***

*Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Panel B: Market share indicator is the company’s shipment value divided by total shipment values.

	F statistics	P-value
$SCIT_i$	3.37	0.074*
$OCIT_i$	7.66	0.009***
CIT_i	6.72	0.013**
PN_i	8.43	0.006***
INV_i	7.49	0.009***

*Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Table 5

Results of complementary effect of innovation and market share on firm value

$$P_{i,t} = Y_{i,t} + \lambda_{1k}[X^{B}_{i,t}(1-\tau_{i,t}) - rY_{i,t-1} - RD_{i,t}] + \lambda_{2k}[RD_{i,t}\tau_{i,t}] + \ell_k Z_{ki} + \theta_k (Z_{ki} \times S_{i,t}) \quad (11)$$

Panel A: Market share indicator is the company's sale divided by total sales.

	Equation (11)				
Patent (Z_{ki})	PN_i	INV_i	CIT_i	$SCIT_i$	$OCIT_i$
Z_{ki}	0.0994 (6.8568)***	0.0453 (4.7150)***	0.0605 (9.4570)***	0.2760 (8.3992)***	0.0756 (9.0825)***
$Z_{ki} \times S_{i,t}$	0.0279 (5.1073)***	0.0111 (2.9384)***	0.0274 (4.5991)***	0.4117 (7.8553)***	0.0280 (7.5651)***
Y_i	0.1824 (0.9137)	0.8669 (4.0255)***	0.6015 (5.7063)***	0.6105 (5.1656)***	0.6189 (5.7428)***
Abnormal return	14.5952 (12.8978)***	13.6006 (8.6881)***	14.5046 (20.2591)***	13.7822 (17.1967)***	14.5994 (19.7737)***
$RD_{i,t}\tau_{i,t}$	17.2389 (9.9861)***	16.0534 (7.1921)***	16.5476 (14.6359)***	16.0704 (13.0590)***	16.5894 (14.2120)***
Constant	0.6212 (0.9050)	0.9024 (1.0340)	0.0744 (0.1415)	0.5765 (1.2689)	-0.0153 (-0.0813)
R^2	0.9765	0.9618	0.9866	0.9835	0.9858
Adjusted R^2	0.9531	0.9562	0.9846	0.9811	0.9837
Partial F	32.1837***	13.0482***	69.1846***	53.1109***	64.3901***
LR	41.7392***	22.2842***	64.0031***	55.7994***	61.7272***

*Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Panel B: Market share indicator is the company's shipment value divided by total shipment values.

	Equation (11)				
Patent (Z_{ki})	PN_i	INV_i	CIT_i	$SCIT_i$	$OCIT_i$
Z_{ki}	0.0052 (1.9703)**	0.0178 (1.0067)	0.0224 (2.1001)**	0.1384 (1.9315)*	0.0302 (2.5213)**
$Z_{ki} \times S_{i,t}$	0.0065 (1.7684)*	0.0032 (1.3889)	0.0100 (4.5991)***	0.0192 (1.3007)	0.0130 (5.5019)***
Y_i	0.7652 (3.8232)***	0.8669 (4.0255)***	0.7824 (5.7742)***	1.1560 (7.4495)***	0.7071 (5.6098)***
Abnormal return	12.0947 (7.5010)***	12.4732 (6.8004)***	9.1919 (5.9626)***	13.3505 (6.5367)***	8.8696 (6.5213)***
$RD_{i,t}\tau_{i,t}$	13.2226 (6.4946)***	13.7391 (5.9703)***	10.5952 (5.9999)***	13.7052 (5.5976)***	10.5123 (6.7145)***
Constant	1.1360 (1.2831)	1.2689 (1.3048)	0.9260 (1.3151)	1.1963 (1.2689)	0.7957 (1.2418)
R^2	0.9620	0.9547	0.9755	0.9557	0.9798
Adjusted R^2	0.9564	0.9481	0.9719	0.9492	0.9768
Partial F	13.2692***	8.2932***	30.1371***	8.8874***	40.2982***
LR	22.4828***	15.4396***	39.9874***	16.3450***	47.7154***

*Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

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