The Persistence and Market Reaction of R&D Investment

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Abstract

The study investigates the value relevance of R&D investment and the reactions of investors in Korean stock markets over the period of 2001-2008. This paper examines whether R&D investment is associated with equity value and whether the information of R&D investment is truly reflected on the Korean stock markets. Consistent with the hypothesis and prior researches, the empirical results of this paper documents that R&D investment is significantly related to the market value of equity and Korean investors quickly recognize the implication of R&D investment information.

Keywords: R&D investment, Value relevance, Market reaction, Korean stock markets

1. Introduction

The prior empirical research about the value relevance of R&D investment generally reports that the R&D investment is significantly associated with the market value of equity (Hirschey and Weygandt, 1985; Titman and Wessels, 1988; Bublitz and Entredge, 1989; Sougiannis, 1996; Hall, 1999; Aboody and Lev, 2001).

According to the efficient market theory, if the financial market is efficient all information about business should be quickly reflected in the market value of equity (Fama, 1970). Contrary to this, some prior research reports that security prices adjust slowly to the information on R&D investment (Chan, Lakonishok, and Sougiannis, 2001; Daniel and Titman, 2006; Eberhart, Maxwell, and Siddique, 2004).

Other literature documents that R&D investments are usually underestimated by market participants (Guo et al., 2006) due to the information asymmetry (Aboody and Lev, 2000) and uncertainty of potential future cash flows from the R&D investment (Chan, Lakonish, and Sougiannis, 2001; Eberhart, Maxwell, and Siddique, 2004).

Based on the arguments of prior literature, the paper argues that even though R&D investment can generate potential future cash flows, the stock market investors do not truly recognize the information content on R&D investment due to the information asymmetry and uncertainty of potential benefits from the R&D activity.

To examine this argument, the study investigates whether R&D investment is positively associated with one year after earnings and market participants truly acknowledge the information content on it in the Korean stock market over the period of 2001-2008. Most notably, this paper performs multiple regressions and Mishkin (1983) test for all samples divided into several subgroups such as, KOSPI/KOSDAQ, big/small & medium, manufacturing/nonmanufacturing and high technology/low technology to observe characteristics of R&D persistence and market reaction in the Korean financial markets.

The study is organized as follows. Section 2 outlines related prior literature which investigates the value relevance of R&D investment and market reactions on it. Section 3 develops the hypothesis and empirical models used in this paper. Section 4 discusses the empirical results of this paper. Section 5 concludes the study.

2. Literature Review

2.1 Prior literatures about value relevance of R&D investment

Much of the previous literature on this topic has documented that R&D investment can promote productivity and create firm value (Griliches and Mairesse, 1984; Hirschey, 1982; Hirschey and Weygandt, 1985; Bublitz and Entredge, 1989; Chauvin and Hirschey, 1993; Sougiannis, 1994; Lev and Sougiannis, 1996; Hall, 1999). For example, Griliches and Mairesse (1984) report that R&D activities have value relevance in high-tech industries.

Hirschey and Weygandt (1985) document that R&D is significantly associated with equity value for firms with high R&D intensity. Bublitz and Ettredge (1989) and Chauvin and Hirschey (1993) also report that R&D investment is positively related to equity value. Especially, Sougiannis (1994), Lev and Sougiannis (1996), and Hall (1999) show that R&D investment is positively associated with not only current equity value but also foreseeable future firm value.

In Korea, Choi and Jung (2001), Jung and Choi (2004), Ahn and Kwon (2006) document that R&D investment is significantly associated with firm innovation which can promote productivity. They also show that R&D activity has a significantly positive relationship with firm value.

2.2 Previous studies on the market participants' recognition of R&D investment

Fama (1970) tests the hypothesis that the capital market is so efficient that it can reflect all value relevant information on stock prices. He shows strong empirical evidence supporting the hypothesis of market efficiency. According to Fama (1970), all financial market participants act so immediately on all value relevant information that the security prices truly reflect the expectations of investors.

However, some researchers have raised questions about the efficient market theory and test whether stock prices immediately reflect the knowledge and expectations of all market participants. For example, Summers (1986) and Poterba and Summers (1988) report that the stock market does not rationally reflect value relevant public information on security prices. DeBondt and Thaler (1995) report that many market participants are usually subject to surges of pessimism and optimism that cause overreaction to past events.

Other literature argues that R&D investment is the main reason for the underestimation or overestimation of stock prices in financial markets (Hall, 1993; Aboody and Lev, 2000; Eberhart, Maxwell, and Siddique, 2004; Luo, 2005). For instance, Eberhart, Maxwell, and Siddique (2004) also investigate investors' reaction to R&D information in financial markets. The empirical results of their paper show that market participants underestimate the potential cash flow of R&D investment.

Aboody and Lev (2000) argue that R&D may create information asymmetry and it can be the reason for the underestimation of R&D investment. In the same context, Hall (1993) reports that a long time is required until R&D investment create future cash flows, moreover because R&D has uncertainty, investors cannot expect whether the R&D project will succeed or not. Luo (2005) also reports that because of information asymmetry, market participants are less knowledgeable about M&A between high-tech companies than other contracts.

3. Hypothesis and Empirical Model

3.1 Study Hypothesis

This paper examines the persistence of R&D investment by testing whether current year R&D investments are associated with one year after earnings performance. To do this, the study tests the following hypotheses;

Hypothesis 1 (H-1): Current year R&D investment is positively associated with one year after accounting earnings.

This paper assumes that because of the information asymmetry and uncertainty related to R&D investment market participants underestimates the expected benefits created by R&D activity. Specifically, the study investigates whether the security market does recognize the future cash flows created by R&D investment. If a financial market truly realizes and reflects the information content of R&D investment, we can expect future positive abnormal returns. Therefore, this paper assumes that R&D investment will generate future positive abnormal returns. To test this assumption, this paper develops the following hypothesis;

Hypothesis 1 (H-2): The investors of Korean stock markets fully recognize the information content of R&D investment.

3.2 Empirical Model for Hypotheses

According to the efficient market hypothesis, if some information is positively associated with future returns, the market is not efficient. In the same way, if R&D information has positive relationship with future stock returns,

the information is mispriced by investors. Therefore, in order to examine whether R&D information is significantly related to the mispricing of the future potential cash flows from R&D investment, this paper basically employs Mishkin's (1983) empirical model used in Sloan (1996).

Mishkin's (1983) empirical model is to test the rational reaction of market participants to accounting information. By testing Mishkin's (1983) model, this paper provides a comparison between current pricing and forecasted future pricing of R&D investment in the Korean security market.

$$E_{t+1}=\gamma_0+\gamma_1 EBFRND_t+\gamma_2 RND_t+\varepsilon_{t+1} \quad (1)$$

$$AR_{t+1}=\alpha_0+\beta_1(E_{t+1}-\gamma_0^*-\gamma_1^* EBFRND_t-\gamma_2^* RND_t)+\varepsilon_{t+1} \quad (2)$$

Where, E_{t+1} (next year accounting earnings) is defined as operating income deflated by total assets of the year t+1. $EBFRND_t$ is current year operating income before deducting total R&D investment of year t (current year accounting earnings), RND_t is total R&D investment in period t deflated by total assets of year t, and AR_{t+1} is abnormal stock returns of year t+1.

Specifically, this paper measures total R&D investment as the following equation (a).

$$RND_t=CRDE_t+ORDE_t=BSRDE_t-BSRDE_{t-1}+ISRDAM_t+MCRDAM_t+ISRDE_t+MCRDE_t \quad (a)$$

Where, RND_t : total R&D investment in period t, $CRDE_t$: total capitalized R&D costs in period t, $ORDE_t$: total ordinary R&D costs in period t, $BSRDE_t$: development costs reported on a balance sheet at the end of year t, $BSRDE_{t-1}$: development costs reported on a balance sheet at the end of year t-1, $ISRDAM_t$: amortization of development costs reported on income statement in period t, $MCRDAM_t$: amortization of development costs reported on statement of the costs of goods manufactured in period t, $MCRDE_t$: research expenses reported on statement of the costs of goods manufactured in period t.

γ_1 and γ_2 are the coefficients of accounting earnings and R&D investment. Equation (1) examines the value relevance of R&D investment by measuringγ_2. If market participants correctly expect the information content of R&D investment ($\gamma_2=\gamma_2^*$), it implies that security mispricing of R&D investment does not exist, so this study can assume that market efficient inevitably exist in the Korean security markets. This paper examines this assumption for R&D investment by testing equation (2).

4. Empirical Results

4.1 Sample Selection and Data Source

The paper employs all the necessary sample data from the KIS-VALUE (Korea Investors Service-Financial Analysis System) database. The analysis data spans the 8-year period from 2001 to 2008. In the process of data collection, the study includes firms with accounting earnings and R&D data for empirical test, whereas this paper excludes financial banking, insurance, public business firms and impairment of capital firms on the KIS-VALUE database. Before going into the main empirical tests this paper excludes ultimate outliers with Cook's Distance greater than 0.5 and absolute value of student residuals greater than 2. <Table 1> presents the data collection process of sample data over the period from 2001 to 2008 in the Korean financial markets.

Insert Table 1 about here

4.2 Empirical Results

4.2.1 Descriptive Statistics

<Table 2> presents descriptive statistics for firm-year sample data of this paper. The study identifies 11,415 firm-year data for the period of 2001–2008. Means of AR_{t+1} is 0.08570, and minimum and maximum values are -1.61806 and 50.72883 separately. Means of E_{t+1} is 0.01308; its minimum value is -6.65490. Means of $EBFRND_t$ is -0.02504; its maximum value is 28.32598. Total Means of RND_t is -0.04442; its standard deviation is 0.49348.

Insert Table 2 about here

4.2.2 Correlation Analysis

<Table 3> shows the result of pearson correlation analysis for data used in this paper. AR, E, and EBFRND are positively correlated at the 5% and 1% level of significance, while AR and RND are negatively correlated at the 10% level of significance. And the correlation between RND and EBFRND also shows a negatively significant

relationship at the 1% level. RND shows negative correlations with AR and BFRND, but it has positive correlation with E. These results suggest that AR, E and EBFRND are positively related to each other, while RND is not.

Insert Table 3 about here

4.2.3 The Persistence of Accounting Earnings and R&D Investment

This paper carries out regressions to investigate persistence of R&D investment in the Korean stock markets. The study presents the regression result on the persistence of R&D investments over the period from 2001 to 2008. The study performs multiple regressions for all samples divided into several subgroups such as, KOSPI/KOSDAQ, big/small & medium, manufacturing/nonmanufacturing, and high technology/low technology to observe characteristics of R&D persistence in the Korean financial markets.

This paper also performs the nonlinear generalized least square regressions with total and subgroup samples to investigate the investors' response to the information of R&D investment and accounting earnings. The study split total samples into KOSPI/KOSDAQ, big/small & medium, manufacturing/nonmanufacturing, and high technology/low technology to investigate the change of market reaction in the Korean stock markets.

4.2.3.1 The Persistence and Market Reaction of R&D Investment: Total Firm

<Table 4> shows the persistence and market response of R&D activity in total sample firm. The empirical results present that the significant R&D and earnings persistence exists in total sample regressions which reject the null hypothesis at the 1% level of significance. This result indicates that there exists a significant relationship between current earnings/R&D and one year after earnings performance.

This paper carries out the nonlinear generalized least square regression of one year after abnormal returns on current earnings and R&D investment in total sample. <Table 4> shows that the coefficients of γ_1 is 0.208925 and the coefficients of γ_1^* is -0.30928 in total samples. The likelihood ratio statistics ($\gamma_1=\gamma_2^*$) in the nonlinear generalized least square regression shows significance at the 1% level of significance.

<Table 4> also presents the coefficients of γ_2 is 0.217219 and the coefficients of γ_2^* is -0.23141 in the total sample. The likelihood ratio statistics ($\gamma_2=\gamma_2^*$) in the nonlinear generalized least square regressions are significant at the 1% level of significance.

This result indicates that the market participants in Korean financial market fail to expect the information content of R&D investment and accounting earnings for stock prices. This result also suggests that Korean investors usually underestimate the persistence of R&D investment and accounting earnings.

Insert Table 4 about here

4.2.3.2 The Persistence and Market Reaction of R&D Investment: KOSPI vs. KOSDAQ

<Table 5> presents the persistence and market reaction of R&D investment in the KOSPI and the KOSDAQ sample groups. The KOSPI sample is defined as firms listed in the Korea Composite Stock Price Index and the KOSDAQ is defined as firms listed in Korea Securities Dealers Automated Quotation.

The empirical result of this paper shows that R&D and earnings persistence exists at the 1% level of significance both in the KOSPI and the KOSDAQ sample firms. But, the coefficient of EBFRND (0.36937) and RND (0.38146) of the KOSDAQ group are steeper than those of KOSPI group (0.02664, 0.02280). In addition, the adjusted R^2 of the KOSDAQ group (0.3867) is greater than that of KOSPI (0.0057).

This result indicates that there exists a significantly positive relationship between current earnings/R&D and one year after earnings performance both in the KOSPI and the KOSDAQ sample. The result also suggests that the persistence intensity of R&D and earnings in the KODSAQ group is higher than those in the KOSPI.

This paper also performs the nonlinear generalized least square regression of one year after abnormal returns on current earnings and R&D investment both in the KOSPI and the KOSDAQ samples. <Table 5> shows that the coefficients of γ_1 are 0.026643 and 0.368937, the coefficients of γ_1^* are -0.00416 and -2.05932 in the KOSPI and the KOSDAQ respectively. The likelihood ratio statistics ($\gamma_1=\gamma_1^*$) in the nonlinear generalized least square regression is positively significant at the 1% level in the KOSAQ group, but it is not significant in the KOSPI group.

<Table 5> also presents the coefficients of γ_2 are 0.022798 and 0.381011, the coefficients of γ_2^* are 0.022378 and -1.78754 in the KOSPI and the KOSDAQ respectively. The likelihood ratio statistics ($\gamma_2=\gamma_2^*$) in the

nonlinear generalized least square regressions is significant at the 1% level in the KOSDAQ group, whereas it does not shows significance in the KOSPI group.

This result shows that participants in the KOSPI market correctly anticipate the information of R&D activity and accounting earnings for stock prices, whereas investors in the KOSAQ market does not fully expect the information content of them. The results also suggest that investors in the KOSDAQ market usually underestimate the persistence of R&D investments and accounting earnings.

Insert Table 5 about here

<Table 6> shows the persistence and market response of R&D investments in Big and Small & Medium firm groups. Big firm sample is defined as firms that have more than 1 thousand employees or assets amount of 500 billion won (USD 416,000,000) and Small & Medium firm sample is defined as firms not included in Big firm group.

The results present current R&D and accounting earnings have significant relationship with one year after accounting earnings at the 1% level of significance both in Big and Small & Medium firm samples. But, the coefficients of EBFRND (0.37977) and RND (0.37729) in Big firm groups are steeper than those of Small & Medium firm groups (0.21654, 0.23257). In addition, the adjusted R^2 of Big firm group (0.3840) is greater than that of the Small & Medium firm sample (0.1786).

This result suggests that there exists a significantly positive relationship between current accounting earnings/R&D activity and one year after accounting performance both in Big and Small & Medium firm groups. The result also indicates that the persistence degree of R&D and earnings in Big firm groups is higher than those in Small & Medium firm groups.

This paper also carries out the nonlinear generalized least square regression of one year after abnormal stock returns on current accounting earnings and R&D both in Big and Small & Medium firm groups. <Table 6> shows that the coefficients of γ_1 are 0.379743 and 0.216222, the coefficients of γ_1^* are 0.075078 and -0.95235 in Big firm and Small & Medium groups respectively. The likelihood ratio statistics ($\gamma_1=\gamma_1^*$) in the nonlinear generalized least square regression is significant at the 1% level both in Big firm and Small & Medium firm groups.

<Table 6> also shows the coefficients of γ_2 are 0.377268 and 0.232228, the coefficients of γ_2^* are 0.087549 and -0.78206 in the KOSPI and KOSDAQ respectively. The likelihood ratio statistics ($\gamma_2=\gamma_2^*$) in the nonlinear generalized least square regressions presents significance at the 1% level both in Big firm and Small & Medium firm groups.

This result presents investors both on Big firm and Small & Medium firm groups do not fully expect the information content of R&D investment and accounting earnings for stock prices. This result also suggests that investors both on Big firm and Small & Medium firm groups underestimate the persistence of R&D investment and accounting earnings.

Insert Table 6 about here

<Table 7> presents the persistence and market reaction of R&D and accounting earnings in manufacturing and nonmanufacturing firm groups. A manufacturing firm sample is defined as firms included in manufacturing industries of Korean Investors Service industry classification, and nonmanufacturing firm sample is defined as firms not included in manufacturing firm of Korean Investors Service industry classification.

The empirical result shows current R&D and accounting earnings are significantly related to one year after accounting earnings at the 1% level of significance both in manufacturing and nonmanufacturing firm samples. But, the coefficient of EBFRND (0.27652) and RND (0.27947) of nonmanufacturing firm group are steeper than those of manufacturing firm group (0.24846, 0.25647). In addition, the adjusted R^2 of nonmanufacturing firm group (0.3665) is greater than that of manufacturing firm sample (0.1620).

This result indicates that there is a significantly positive relationship between current accounting earnings/R&D activity and one year after accounting performance both in manufacturing and nonmanufacturing firm groups. The result also shows that the persistence degree of R&D investment and accounting earnings in nonmanufacturing firm group is higher than those in the manufacturing firm group.

This study also performs the nonlinear generalized least square regression of one year after abnormal stock returns on current accounting earnings and R&D investment both in manufacturing and nonmanufacturing firm groups. <Table 7> shows that the coefficients of γ_1 are 0.248428 and 0.276063, the coefficients of γ_1^* are

-0.55248 and -0.04271 in manufacturing and nonmanufacturing sample group respectively. The likelihood ratio statistics ($\gamma_1=\gamma_1^*$) in the nonlinear generalized least square regression is significant at the 1% level both in manufacturing and nonmanufacturing firm groups.

<Table 7> also shows the coefficients of γ_2 are 0.256437 and 0.279007, the coefficients of γ_2^* are -0.45689 and 0.005977 in manufacturing and nonmanufacturing firm groups respectively. The likelihood ratio statistics ($\gamma_2=\gamma_2^*$) in the nonlinear generalized least square regressions presents significance at the 1% level both in manufacturing and nonmanufacturing firm groups.

This result presents participants both in manufacturing and nonmanufacturing firm groups do not fully anticipate the information content of R&D investment and accounting earnings for stock prices. This result also shows that participants both in manufacturing and nonmanufacturing firm groups underestimate the persistence of R&D investment and accounting earnings. This result is the same as that of <Table 6>

Insert Table 7 about here

<Table 8> presents the empirical results of persistence and market reaction of R&D and accounting earnings in high technology and low technology firm groups. High and low technology samples are classified as Himmelberg and Petersen (1994) classification. Himmelberg and Petersen (1994) includes chemicals, pharmaceuticals, metal, electronic components, medical, precision and optical instruments, electrical equipment in high technology industry and they include the others in low technology industry

The empirical result shows current R&D and accounting earnings are significantly related to one year after accounting earnings at the 1% level of significance both in the high technology and low technology firm samples. But, the coefficient of EBFRND (0.30521) and RND (0.30981) of low technology firm groups are steeper than those of manufacturing firm groups (0.20986, 0.21807). In addition, the adjusted R^2 of the low technology firm group (0.3806) is greater than that of the high technology firm sample (0.1421).

This result shows that there is a significantly positive relationship between current accounting earnings/R&D activity and one year after accounting performance both in high technology and low technology firm groups. The result also shows that the persistence degree of R&D investment and accounting earnings in low technology firm group is higher than those in the high technology firm group.

This study also carries out the nonlinear generalized least square regression of one year after abnormal stock returns on current accounting earnings and R&D activity both in high technology and low technology firm groups. <Table 8> shows that the coefficients of γ_1 are 0.209819 and 0.304921, the coefficients of γ_1^* are -0.42584 and -0.32166 in high technology and low technology sample groups respectively. The likelihood ratio statistics ($\gamma_1=\gamma_1^*$) in the nonlinear generalized least square regression is significant at the 1% level both in high technology and low technology firm groups.

<Table 8> also shows the coefficients of γ_2 are 0.218019 and 0.309511, the coefficients of γ_2^* are -0.35772 and -0.20918 in high technology and low technology firm groups respectively. The likelihood ratio statistics ($\gamma_2=\gamma_2^*$) in the nonlinear generalized least square regressions presents significance at the 1% level in high technology and 5% of significance in low technology firm groups.

This result presents stock market investors both on high technology and low technology firm groups do not fully anticipate the information content of R&D activity and accounting performance for security prices. This result also suggests that market participants both in high technology and low technology firm groups underestimate the persistence of R&D activity and accounting performance.

Insert Table 8 about here

5. Conclusions

The paper examines the persistence of R&D investments and market reactions on it over the period of 2001-2008. At first, this study investigates the persistence of R&D activity by testing whether current year R&D investment is significantly related to one year after accounting performance. The paper also examines the market reactions on R&D investment by testing the nonlinear generalized least square regression of one year after abnormal stock returns on current accounting earnings and R&D. From these tests, this paper can show whether the participants of the Korean stock markets precisely recognize the information contents of R&D investment.

For this, the study tests two hypotheses. First, current R&D investment is positively associated with one year after accounting earnings. Second, the investors of Korean stock markets precisely acknowledge the information content of R&D investment.

Consistent with the first hypothesis of this paper, the empirical results of this paper show that current year R&D investment is positively associated with one year after accounting performance. This result suggests that R&D investments have significant persistence in the Korean stock markets.

However, the empirical results do not support the second hypothesis of this paper. The result of this paper documents that market participants do not fully recognize the information content of R&D activity except investors of the KOSPI market. This result suggests that, the Korean investors usually underestimate the information content of R&D activity.

The findings of this paper have important implications for accounting literature examining the persistence and information asymmetric of R&D investment. The paper documents that the reaction of market participants to the R&D investment information with long delay in the Korean stock markets.

The results of this paper are similar to previous empirical results. Many prior studies report that general market participants slowly respond or react to the information of R&D investment in security markets. But for firms in the KOSPI group, market participants quickly response to the information of R&D investments. These results may be merely restricted to the Korean stock markets, or this could be the truth.

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Table 1. Selection of sample firms

Sum of Listed companies at the end of 2001-2008(firm-year)	14,048
Minus (-) : Firms that do not settle their accounts in December Financial banking businesses Issues in administration Firms with missing financial data capital encroachment firms	(2,633)
Total sample firms(firm-year)	11,415

Table 2. Descriptive Statistics

Year	Number	Variables	Mean	Standard deviation	Min	Max
2001-2008	11,415	AR_{t+1}	0.08570	0.89529	-1.61806	50.72883
		E_{t+1}	0.01308	0.36869	-6.65490	28.53117
		$EBFRND_t$	-0.02504	0.62702	-19.73749	28.32598
		RND_t	0.04442	0.49348	0	19.70033

Variable definitions: AR_{t+1}= Abnormal stock returns at the end of fiscal year t+1, where year t+1 is the event year; E_{t+1} = Accounting earnings in period t+1 deflated by total assets of year t+1; $EBFRND_t$ = Accounting earnings before deducting total R&D investment in period t deflated by total assets of year t; RND_t = Total R&D investment in period t deflated by total assets of year t.

Table 3. Pearson Correlations

Variables	AR	E	EBFRND	RND
AR	1.00000			
E	0.02090	1.00000		
	(0.0256)			
EBFRND	0.03316	0.03306	1.00000	
	(0.0004)	(0.0004)		
RND	-0.01629	0.01139	-0.78742	1.00000
	(0.0819)	(0.2236)	(<.0001)	

1) Pearson's coefficient of correlation, two-sided test, Variable definitions: Refer to <Table 2>

2) * p < 0.1, ** p < 0.05, *** p < 0.01

Table 4. Persistence and Market Reaction of R&D Investment: Total Firm

(A) Equation: $E_{t+1}=\gamma_0+\gamma_1 EBFRND_t+\gamma_2 R^2$					
Number	Variables	Coefficients	t value	Adj R^2	F-value
11,415	Intercept(γ_0)	0.03014	33.4**	0.1758	1168.14
	$EBFRND_t(\gamma_1)$	0.20924	48.06**		
	$RND_t(\gamma_2)$	0.21755	46.07**		

(B) Forecasting equation: $E_{t+1}=\gamma_0+\gamma_1 EBFRND_t+\gamma_2 RND_t+\varepsilon_{t+1}$

Valuation equation: $AR_{t+1}=\alpha_0+\beta_1(E_{t+1}-\gamma_0^*-\gamma_1^* EBFRND_t-\gamma_2^* RND_t)+\varepsilon_{t+1}$

Number	γ_1	γ_1^*	γ_2	γ_2^*	Test of market efficiency	Likelihood ratio statistic	Marginal significance level
11,415	0.208925**	-0.30918*	0.217219	-0.23141	$\gamma_1=\gamma_1^*$	26.42	<.0001
					$\gamma_2=\gamma_2^*$	16.84	<.0001

Variable definitions: Refer to <Table 2>, * (**): Significant at the .05 (.01) level.

Table 5. Persistence and Market Reaction of R&D Investment: KOSPI vs. KOSDAQ

Equation: $E_{t+1}=\gamma_0+\gamma_1 EBFRND_t+\gamma_2 RND_t+\varepsilon_{t+1}$						
Group	Number	Variables	Coefficients	t value	Adj R^2	F-value
KOSPI	4,524	Intercept(γ_0)	0.03416	27.84**	0.0057	13.73
		$EBFRND_t(\gamma_1)$	0.02664	5.01**		
		$RND_t(\gamma_2)$	0.02280	3.83**		
KOSDAQ	6,891	Intercept(γ_0)	0.02448	22.34**	0.3867	1989.71
		$EBFRND_t(\gamma_1)$	0.36937	62.59**		
		$RND_t(\gamma_2)$	0.38146	61.20**		

Forecasting equation: $E_{t+1}=\gamma_0+\gamma_1 EBFRND_t+\gamma_2 RND_t+\varepsilon_{t+1}$

Valuation equation: $AR_{t+1}=\alpha_0+\beta_1(E_{t+1}-\gamma_0^*-\gamma_1^* EBFRND_t-\gamma_2^* RND_t)+\varepsilon_{t+1}$

Group	Number	γ_1	γ_1^*	γ_2	γ_2^*	Test of market efficiency	Likelihood ratio statistic	Marginal significance level
KOSPI	4,524	0.026643**	-0.00416	0.022798**	0.022378	$\gamma_1=\gamma_1^*$	0.29	0.5930
						$\gamma_2=\gamma_2^*$	0.01	0.9352
KOSDAQ	6,891	0.368937**	-2.05932	0.381011**	-1.78754	$\gamma_1=\gamma_1^*$	19.59	<.0001
						$\gamma_2=\gamma_2^*$	14.00	0.0002

Variable definitions: Refer to <Table 2>, * (**): Significant at the .05 (.01) level.

Table 6. Persistence and Market Reaction of R&D Investment: Big vs. Small & Medium

Equation: $E_{t+1}=\gamma_0+\gamma_1 EBFRND_t+\gamma_2 RND_t+\varepsilon_{t+1}$						
Group	Number	Variables	Coefficients	t value	Adj R^2	F-value
Big	3,734	Intercept(γ_0)	0.02949	41.03**	0.3840	1034.66
		$EBFRND_t$(γ_1)	0.37977	45.37**		
		RND_t(γ_2)	0.37729	44.50**		
Small & Medium	7,681	Intercept(γ_0)	0.02321	17.18**	0.1786	801.66
		$EBFRND_t$(γ_1)	0.21654	39.51**		
		RND_t(γ_2)	0.23257	37.67**		

Forecasting equation: $E_{t+1}=\gamma_0+\gamma_1 EBFRND_t+\gamma_2 RND_t+\varepsilon_{t+1}$

Valuation equation: $AR_{t+1}=\alpha_0+\beta_1(E_{t+1}-\gamma_0^*-\gamma_1^* EBFRND_t-\gamma_2^* RND_t)+\varepsilon_{t+1}$

Group	Number	γ_1	γ_1^*	γ_2	γ_2^*	Test of market efficiency	Likelihood ratio statistic	Marginal significance level
Big	3,734	0.379743**	0.075078	0.377268**	0.087549	$\gamma_1=\gamma_1^*$	16.91	<.0001
						$\gamma_2=\gamma_2^*$	14.91	0.0001
Small & Medium	7,681	0.216222**	-0.95235	0.232228**	-0.78206	$\gamma_1=\gamma_1^*$	14.96	0.0001
						$\gamma_2=\gamma_2^*$	8.88	0.0029

Variable definitions: Refer to <Table 2>, * (**): Significant at the .05 (.01) level.

Table 7. Persistence and Market Reaction of R&D Investment: Manufacturing vs. Nonmanufacturing

Equation: $E_{t+1}=\gamma_0+\gamma_1 EBFRND_t+\gamma_2 RND_t+\varepsilon_{t+1}$						
Group	Number	Variables	Coefficients	t value	Adj R^2	F-value
Manufacturing	7,913	Intercept(γ_0)	0.03126	28.85**	0.1620	743.12
		$EBFRND_t$(γ_1)	0.24846	38.35**		
		RND_t(γ_2)	0.25647	37.75**		
Nonmanufacturing	3,502	Intercept(γ_0)	0.02309	15.45**	0.3665	929.09
		$EBFRND_t$(γ_1)	0.27652	42.97**		
		RND_t(γ_2)	0.27947	37.37**		

Forecasting equation: $E_{t+1}=\gamma_0+\gamma_1 EBFRND_t+\gamma_2 RND_t+\varepsilon_{t+1}$

Valuation equation: $AR_{t+1}=\alpha_0+\beta_1(E_{t+1}-\gamma_0^*-\gamma_1^* EBFRND_t-\gamma_2^* RND_t)+\varepsilon_{t+1}$

Group	Number	γ_1	γ_1^*	γ_2	γ_2^*	Test of market efficiency	Likelihood ratio statistic	Marginal significance level
Manufacturing	7,913	0.248428**	-0.55248	0.256437**	-0.45689	$\gamma_1=\gamma_1^*$	13.89	0.0002
						$\gamma_2=\gamma_2^*$	10.02	0.0015
Nonmanufacturing	3,502	0.276063**	-0.04271	0.279007**	0.005977	$\gamma_1=\gamma_1^*$	19.05	<.0001
						$\gamma_2=\gamma_2^*$	10.35	0.0013

Variable definitions: Refer to <Table 2>, * (**): Significant at the .05 (.01) level.

Table 8. Persistence and Market Reaction of R&D Investment: High Technology vs. Low Technology

Equation: $AR_{t+1}=\alpha_0+\beta_1 (E_{t+1}-\gamma_0^*-\gamma_1^*EBFRND_t-\gamma_2^*RND_t)+\varepsilon_{t+1}$						
Group	Number	Variables	Coefficients	t value	Adj R^2	F-value
High Technology	5,563	Intercept(γ_0)	0.03040	20.08**	0.1421	449.62
		$EBFRND_t$(γ_1)	0.20986	29.78**		
		RND_t(γ_2)	0.21807	29.28**		
Low Technology	5,852	Intercept(γ_0)	0.02643	28.02**	0.3806	1667.85
		$EBFRND_t$(γ_1)	0.30521	57.53**		
		RND_t(γ_2)	0.30981	50.57**		

Forecasting equation: $E_{t+1}=\gamma_0+\gamma_1 EBFRND_t+\gamma_2 RND_t+\varepsilon_{t+1}$

Valuation equation: $AR_{t+1}=\alpha_0+\beta_1(E_{t+1}-\gamma_0^*-\gamma_1^*EBFRND_t-\gamma_2^*RND_t)+\varepsilon_{t+1}$

Group	Number	γ_1	γ_1	γ_2	γ_2	Test of market efficiency	Likelihood ratio statistic	Marginal significance level
High Technology	5,563	0.209819**	-0.42584*	0.218019**	-0.35772	$\gamma_1=\gamma_1^*$	24.14	<.0001
						$\gamma_2=\gamma_2^*$	17.73	<.0001
Low Technology	5,852	0.304921**	-0.32166	0.309511**	-0.20918	$\gamma_1=\gamma_1^*$	11.06	0.0009
						$\gamma_2=\gamma_2^*$	5.68	0.0171

Variable definitions: Refer to <Table 2>, * (**): Significant at the .05 (.01) level.