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EFFECT OF R&D ON FIRMS' GROWTH: DISCREPANCY BETWEEN SALES GROWTH AND EMPLOYMENT EXPANSION

Abstract:

In this paper, we analyze the effect of firms' R&D investment on sales growth and employment expansion. We attempt to shed light on the R&D investment effect by comparing the difference of R&D influence on these two growth dimensions. The estimation results of the panel fixed-effect model show that the previous year's R&D investment has a significant and positive association with the current year's sales growth but does not result in significant employment expansion. We also conduct a two-digit industry-level analysis based on the Korean Standard Industrial Classification (KSIC), using a quantile regression model, to examine how the discrepancy between sales growth and employment expansion differs between industries. Among various manufacturing industries, high-tech industries such as electronics are characterized by large discrepancies. Based on the estimation results, we discuss industrial policies for sustainable growth when a nation such as South Korea follows a high-growth strategy by increasing the rate of R&D investment.

Keywords:

R&D, firm growth, sustainable growth

JEL Classification: L25, O43

1. Introduction

Since companies are profit seeking organizations, profit maximization is a time-honored, typical theoretical framework for modeling firms' economic decision-making and other company activities. However, recently, an increasing number of studies has deviated from the conventions of profit maximization theory to consider a firm as a living organism (Goldberg and Godwin, 2002, de Geus, 1997).

This perspective gives rise to growth becoming an objective performance measure of a firm. When a firm is viewed as an individual living organism, whether it can survive in a competitive market environment naturally would be a matter of first priority and growth has significant implications for survival. In addition, as the economic growth of a region or a country is used as a typical measure of economic prosperity among many macroeconomic indicators, growth is also considered as an important business performance indicator in the dimension of individual companies.

This trend toward stressing company growth can be also found from research addressing the impact of innovative activities, such as R&D, on firm performance. In other words, the number of studies examining the impact of R&D investment on firm growth has been increasing in recognition of growth as a key performance measure of a firm's innovation. In particular, though there was a significant discrepancy between theoretical discussion and empirical findings in the past, the gap has been gradually narrowing recently due to the emergence of many empirical studies with advanced models, such as quantile regression.

This study contributes to a more lucid understanding of the impact of R&D on company growth by analyzing firm growth in two dimensions: sales growth and employment growth. To do so, this study categorizes Korean manufacturing industries based on Hatzichronoglou's (1997) industry classification according to technology level. It also analyzes the impact of R&D on growth in the two dimensions for each industry group to test whether there is any distinction between them. In order to measure a company's growth, most previous research used either the growth rate of sales or the number of employees. However, no research to our knowledge attempted to identify the difference in the effects of R&D on the two dimensions of company growth. The identification of any difference in these two aspects will provide not only a comprehensive understanding of the impact of innovative activities on business performance but also assist in the design of elaborate innovation policies. For instance, in certain industries, if innovative activities do not lead to an increase in employment regardless of its significant impact on sales growth, innovation in such industries is likely to bring growth while employment remains stagnant. If the weight of these industries is large in a country, a national innovation policy for employment growth should be developed if unemployment is to be reduced.

2. Previous literature

The manner in which innovative activities influence enterprise performance is of great interest to both researchers and business practitioners. To this end, various indicators have been used to measure the performance of innovative activities, with numerous studies relying on direct outputs of innovation, such as the number of patent applications and grants. Others have measured the performance of R&D investment using a variety of economic performance indicators, such as profitability (Fryxell, 1990, Watanabe et al., 2009), productivity (Ortega-

Argiles et al., 2011, Balcombe et al., 2005), and a company's market value (Yuhong and Case, 2010, Wu and Wei, 1998).

Some studies focused on firm growth as an indicator of innovation performance, as this study does. Among them, Coad and Rao (2008) is considered one recent influential empirical study that greatly inspired many subsequent studies. That study took the approach that, since R&D activities are accompanied by great uncertainty, traditional analysis examining the average impact of R&D investment on company growth using the ordinary least squares (OLS) method is inadequate to derive accurate conclusions concerning causality between R&D and growth. Thus, they analyzed the relationship using a quantile regression model, which is useful in estimating the coefficients of R&D investment according to the growth quantile. The study determined that R&D investment had a weak positive relationship with company growth on average but substantially affected high growth companies. They argued that R&D investment uncertainty produced these results.

Following Coad and Rao (2008), many researchers conducted empirical studies by analyzing diverse data from different sources. García-Manjón and Romero-Merino (2012) investigated the effect of R&D investment on the sales growth of 1,000 European companies undertaking large R&D investment. Falk (2012) examined the relationship between R&D investment and company growth for the period 1995-2006 using financial data of Austrian companies that had been sponsored by the Austrian Industrial Research Promotion Fund. Interestingly, small companies with less than ten employees accounted for quite a large proportion of the data (about 25%) compared with other dataset subgroups. The author analyzed company growth from two aspects, sales and the number of employees, but found no significant difference between the two.

With current active empirical analyses addressing the impact of innovative activities on company growth, the gap between theoretical and empirical research has been gradually narrowing. However, empirical studies covering a wider variety of countries and data are still required. Accordingly, this study examines the impact of R& D investment on firm growth using the national-scale Business Activities data collected annually by the Korea National Statistical Office. As described in the introduction, this study investigates the impact of R&D on firm growth through two dimensions, sales and the number of employees, and examines whether any distinction can be discerned between the two. In addition, we consider the technical level of industries, such as high-tech industries or low-tech industries, as a major industrial characteristic causing such differences, if any, and empirically test whether the discrepancies between the two dimensions of firm growth differ among these industry groups

3. Data and measures

3.1. Data

The Survey of Business Activities, an authorized national survey, has been conducted by the Korea National Statistical Office since 2006 for all firms with more than 50 employees and a capital base of at least 300 million won (KRW). The survey collector visits every target firm to explain the purpose of the survey and instruct on its completion. The respondent is asked to respond to the questionnaire on site. In some cases, completion of the survey form online is permitted as an auxiliary surveying tool. The main survey items include the firms' financial structure, management performance, the number of organizations and workers, R&D expenses, outsourcing cost, and management direction.

This study used the panel dataset of the Survey of Business Activities for the period 2006-2011. The number of respondents was 11,733 in 2011 though the numbers for the other years differ slightly. The dataset includes all types of industries in South Korea. Within the dataset, manufacturing firms, at around 60%, comprise the overwhelming majority, followed by the wholesale & retail trade industry (8.15%) and information & communications industry (7.4%).

While investigating the relationship between R&D investment and firm growth, we consider the industry technology level as a key environmental factor influencing the relationship. Since this study adopts Hatzichronoglou's (1997) industry classification, only manufacturing firms to which such classification is applicable have been included in this study.

Table 1. Sample Distribution in Manufacturing Industry

KSIC Code	Industries	Number of firms	Share (%)	Technology level
C10	Food Products	1,327	6.56	Low
C11	Beverages	106	0.52	Low
C13	Textiles, Except Apparel	866	4.28	Low
C14	Wearing apparel, Clothing Accessories and Fur Articles	701	3.47	Low
C15	Tanning and Dressing of Leather, Luggage and Footwear	141	0.70	Low
C16	Wood Products of Wood and Cork ; Except Furniture	56	0.28	Low
C17	Pulp, Paper and Paper Products	473	2.34	Low
C18	Printing and Reproduction of Recorded Media	227	1.12	Low
C19	Coke, hard-coal and lignite fuel briquettes and Refined Petroleum Products	30	0.15	Mid-low
C20	Chemicals and chemical products except pharmaceuticals, medicinal chemicals	1,339	6.62	Mid-high
C21	Pharmaceuticals, Medicinal Chemicals and Botanical Products	580	2.87	High
C22	Rubber and Plastic Products	1,430	7.07	Mid-low
C23	Other Non-metallic Mineral Products	672	3.32	Mid-low
C24	Basic Metal Products	1,248	6.17	Mid-low
C25	Fabricated Metal Products, Except Machinery and Furniture	1,172	5.80	Mid-low
C26	Electronic Components, Computer, Radio, Television and Communication Equipment and Apparatuses	2,498	12.35	High
C27	Medical, Precision and Optical Instruments, Watches and Clocks	646	3.19	High
C28	Electrical equipment	1,239	6.13	Mid-high
C29	Other Machinery and Equipment	2,295	11.35	Mid-high
C30	Motor Vehicles, Trailers and Semitrailers	2,542	12.57	Mid-high
C31	Other Transport Equipment	314	1.55	Mid-high
C32	Furniture	156	0.77	Low

C33	Other manufacturing	163	0.81	Low
Total		20,221	100.0	-

3.2. Empirical model

This study examines the effect of R&D investment on the growth of manufacturing firms in South Korea using Coad and Rao's (2008) quantile regression model, which was originally proposed by Koenker and Bassett (1978). Estimating a quantile regression coefficient at a given quantile of τ requires identification of coefficient β that satisfies the following constraint equation.

$$Min\ \frac{1}{n}\left[\sum_{y_i \geq \beta' X_i} \tau \left| y_i - \beta' X_i \right| + \sum_{y_i < \beta' X_i} (1-\tau) \left| y_i - \beta' X_i \right| \right]$$

The detailed specification of the model used for the estimation is as follows:

$$Growth_{i,t} = \alpha + \beta_1 RD_{i,t-1} + \beta_2 Growth_{i,t-1} + \beta_3 Size_{i,t-1} + \beta_4 Ind_{i,t} + \delta_t + \varepsilon_{i,t}$$

3.3. Distribution of growth rate

Figure 1 presents the distribution of sales growth rates, where industries are classified and compared according to technology level: low tech, mid-low tech, mid-high tech, and high tech. Most interestingly, the degree of dispersion in growth rate distribution differs by industry. For low tech industries, the distribution is quite narrow, i.e., a large number of firms cluster around the average value, thereby creating a pronounced peak. In contrast, high tech industries have widely distributed growth rates with a correspondingly low peak. In other words, for high tech industries, there are not only many high growth firms but also many negative growth firms with declining sales. As evident from the graph, this trend is more pronounced in high tech industries compared to mid or low tech industries. It is interesting that the industry classification is based on the average R&D intensity in each industry. To determine the cause of such growth rate distribution for high-tech industries despite significant R&D investment, more in-depth analysis is conducted in Chapter 4 using the quantile regression model to examine the relationship between R&D investment and firm growth rate.

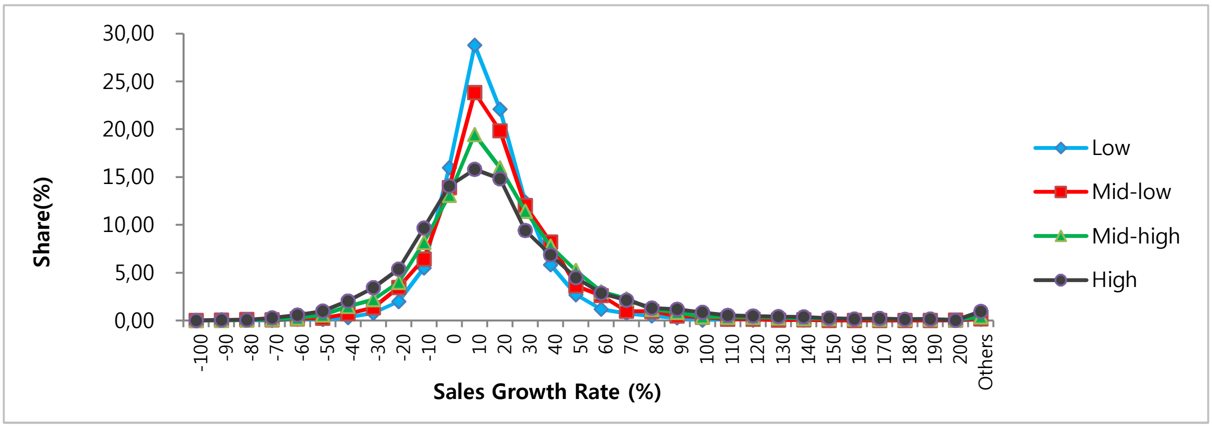


Figure 1. Distribution of sales growth and employment growth according to the industry technology level

4. Results

4.1. Full-sample estimation result

The full-sample estimation results are presented in Table 2 and Table 3.

Table 2

Full-sample estimation results of different models (Sales Growth)

	OLS	FE	Quantile regression (%)				
			10	25	50	75	90
Growth $_{t-1}$	-0.097***	0.133***	-0.0103	-0.00620	-0.00887	-0.0235**	-0.0740***
	(-12.10)	(14.45)	(-0.71)	(-0.76)	(-1.37)	(-2.86)	(-5.61)
Log(sales) $_{t-1}$	-0.011***	-0.833***	-0.00166	-0.00160	0.000	-0.0081***	-0.0143***
	(-6.57)	(-73.18)	(-0.53)	(-0.90)	(0.00)	(-4.58)	(-5.02)
R&D $_{t-1}$	0.460***	0.404***	-0.0192	0.120*	0.282***	0.680***	1.610***
	(8.37)	(5.05)	(-0.19)	(2.14)	(6.34)	(12.06)	(17.76)
Year_2009	-0.101***	-0.0139**	-0.147***	-0.109***	-0.0803***	-0.0923***	-0.107***
	(-16.33)	(-2.62)	(-13.14)	(-17.23)	(-16.02)	(-14.55)	(-10.45)
Year_2010	0.0424***	0.161***	0.0204	0.0314***	0.0539***	0.0558***	0.0414***
	(6.81)	(29.28)	(1.81)	(4.94)	(10.71)	(8.76)	(4.04)
Year_2011	-0.0188**	0.198***	-0.0162	-0.000968	-0.00730	-0.0371***	-0.0609***
	(-3.02)	(33.53)	(-1.44)	(-0.15)	(-1.45)	(-5.83)	(-5.95)
Ind_midlow	-0.0032	0.0340	-0.0671***	-0.0303***	0.00626	0.0331***	0.0496***
	(-0.52)	(0.89)	(-5.99)	(-4.79)	(1.25)	(5.22)	(4.86)
Ind_midhigh	0.00738	0.0465	-0.0978***	-0.0342***	0.0147**	0.0553***	0.0854***
	-1.29	(1.18)	(-9.44)	(-5.84)	(3.18)	(9.42)	(9.05)
Ind_high	-0.0214**	0.0692	-0.157***	-0.0704***	-0.0101	0.0234***	0.0969***
	(-3.16)	(1.70)	(-12.84)	(-10.15)	(-1.84)	(3.36)	(8.68)

Const	0.237*** (12.34)	8.877*** (72.11)	-0.0464 (-1.34)	0.0344 (1.75)	0.0941*** (6.06)	0.291*** (14.78)	0.480*** (15.18)
# of Obs.	16,208						
R2	0.0571	0.0058	-	-	-	-	-
Pseudo-R2	-	-	0.0490	0.0348	0.0269	0.0431	0.0702

Table 3

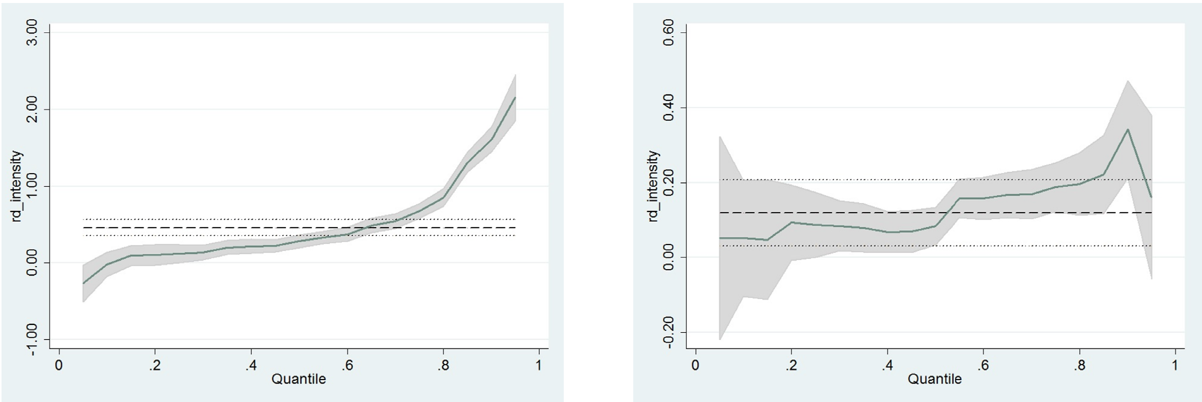
Full-sample estimation results of different models (Employment Growth)

	OLS	FE	Quantile regression (%)				
			10	25	50	75	90
Growth t-1	-0.223***	-0.381***	-0.263***	-0.175***	-0.105***	-0.127***	-0.176***
	(-28.80)	(-44.81)	(-17.21)	(-23.04)	(-22.80)	(-17.93)	(-12.20)
Log(sales) t-1	-0.00134	-0.095***	0.00901**	0.00617***	0.000267	-0.00308*	-0.00382
	(-0.95)	(-10.62)	(3.24)	(4.46)	(0.32)	(-2.38)	(-1.46)
R&D t-1	0.120**	-0.0964	0.0513	0.0870*	0.0837**	0.187***	0.343***
	(2.66)	(-1.23)	(0.58)	(1.97)	(3.14)	(4.54)	(4.09)
Year_2009	0.0217***	0.0258***	0.0225*	0.00892	0.00564	0.0101*	0.0214*
	(4.26)	(5.01)	(2.24)	(1.79)	(1.87)	(2.18)	(2.27)
Year_2010	0.0531***	0.0631***	0.0579***	0.0484***	0.0403***	0.0530***	0.0689***
	(10.47)	(12.24)	(5.78)	(9.73)	(13.44)	(11.41)	(7.31)
Year_2011	0.0361***	0.0638***	0.0475***	0.0346***	0.0284***	0.0332***	0.0359***
	(7.11)	(11.33)	(4.74)	(6.93)	(9.44)	(7.14)	(3.80)
Ind_midlow	0.00306	-0.00792	0.0126	0.0009	0.00222	0.00220	0.0113
	(0.60)	(-0.21)	(1.25)	(0.18)	(0.74)	(0.47)	(1.20)
Ind_midhigh	0.0118*	-0.00428	0.00336	0.00346	0.0107***	0.0219***	0.0221*
	(2.51)	(-0.11)	(0.36)	(0.75)	(3.86)	(5.10)	(2.53)
Ind_high	-0.00351	-0.0638	-0.0711***	-0.0233***	0.00711*	0.0262***	0.0421***
	(-0.63)	(-1.60)	(-6.48)	(-4.28)	(2.16)	(5.15)	(4.07)
Const	-0.00574	1.008***	-0.321***	-0.159***	-0.0143	0.0943***	0.205***
	(-0.37)	(10.30)	(-10.37)	(-10.33)	(-1.54)	(6.57)	(7.05)
# of Obs.	16,208						
R2	0.056	0.0219	-	-	-	-	-
Pseudo-R2	-	-	0.0468	0.0258	0.0153	0.0221	0.0267

Figure 2 graphically illustrates the difference between the OLS coefficient and the quantile regression coefficient of the R&D intensity variable. The OLS coefficient is indicated by a thick dotted line, and the light dotted lines above and below it indicate its confidence interval. An upward angled line intersecting the OLS coefficient line indicates the quantile regression coefficient. The gray area around the angled line is the confidence interval of the quantile regression coefficient.

Whereas the OLS coefficient was constant for every quantile, the quantile regression coefficient increased for higher growth quantiles. This suggests that the effect of R&D intensity on firm growth rate is greater for relatively higher growth firms. However, the coefficient of R&D intensity for low growth firms remained within a negative range, which suggests that, for firms experiencing sales decline, the previous year's large R&D investment will adversely impact sales growth.

In terms of the empirical research model, the results were obvious: the quantile regression coefficient considerably deviated from the confidence interval of the OLS coefficient according to the changes in the growth quantile. This indicates that the quantile regression model can effectively reveal this characteristic of the data, whereas the OLS model cannot.



Sales Growth Employment Growth

Figure 2. OLS vs. Quantile regression coefficient of R&D intensity

4.2. Industrial difference within manufacturing industries

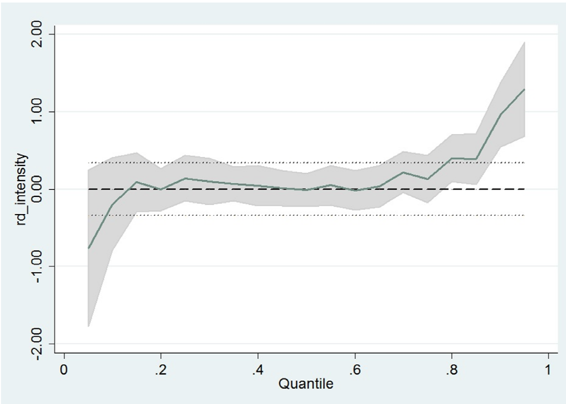
Generally, there is a significant difference in the impact of technological innovation through R&D investment on enterprise performance among industries. The OECD categorizes the technology level of manufacturing industries into four subgroups by level of R&D intensity based on Hatzichronoglou (1997): high technology, medium-high technology, medium-low technology, and low technology. This industry classification is updated when the International Standard Industrial Classification (ISIC) is revised. This study examines the effect of R&D investment on firm growth in each technology level using the OECD classification.

Table 4 exhibits the estimates of R&D investment effect based on an OLS model and a panel fixed effect model for each industry group. Industries with a large positive estimate were C29 (medium-high technology industry) and C27 (high technology industry). This implies that the impact of R&D investment on sales growth rate is greater for high tech and medium-high tech industries than for low tech or medium-low tech industries. However, since the average OLS estimate has limited information to represent the full sample, a quantile regression analysis was conducted for each industry group.

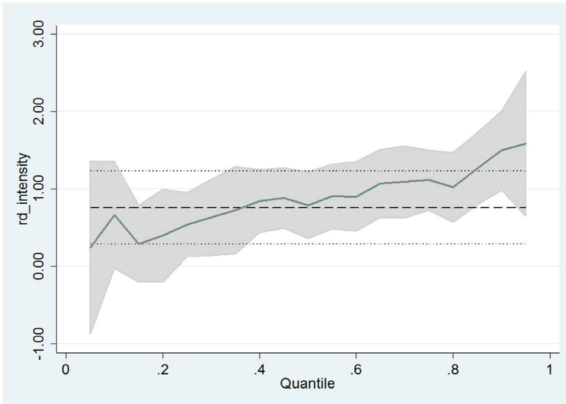
Table 4. The R&D intensity coefficient of different models

	Technological Characteristic of Industry	OLS	FE	Quantile				
				10	25	50	75	90
Sales Growth	Low tech	0.002	0.0315	-0.193	0.141	-0.008	0.135	0.958***
	Mid-low tech	0.761	-0.174	0.667	0.538**	0.791***	1.118***	1.502***

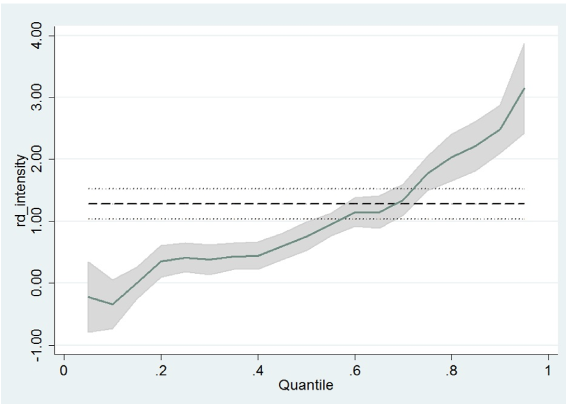
	Mid-high tech	1.281***	0.896***	-0.337	0.418***	0.759***	1.771***	2.484***
	High tech	0.165**	0.335**	-0.046	0.013	0.124*	0.357***	1.108***
Employ ment Growth	Low tech	-0.323	-0.209	-0.617	-0.500***	-0.179***	-0.011	0.279
	Mid-low tech	0.278	0.080	-0.575	-0.212	0.266**	0.727***	1.562***
	Mid-high tech	0.241*	-0.256*	0.073	0.131	0.141**	0.262***	0.464*
	High tech	0.076	-0.088	0.072	0.112	0.074*	0.127**	0.0244



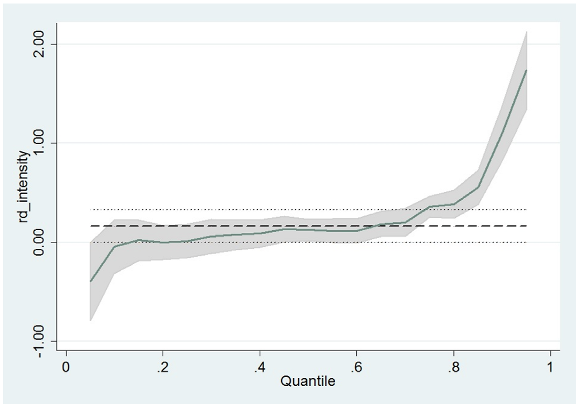
Low Tech Industry



Medium-low Tech Industry

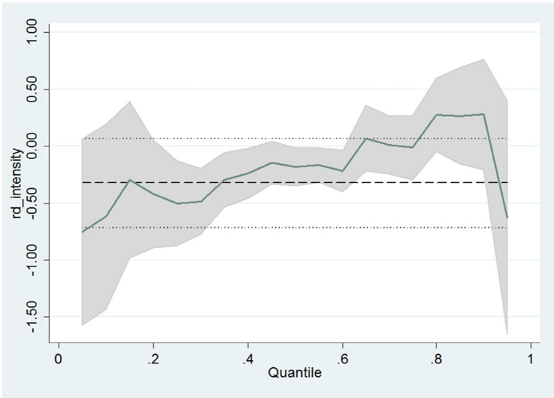


Medium-high Tech Industry

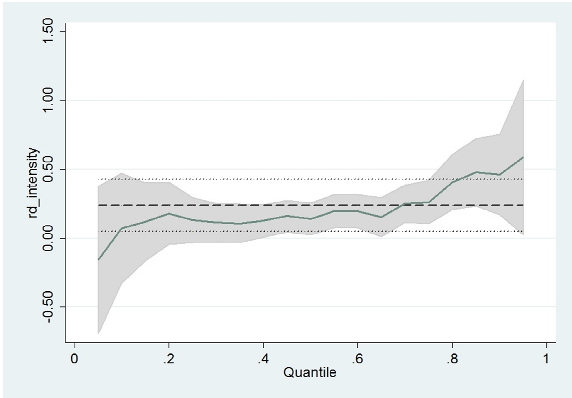


High Tech Industry

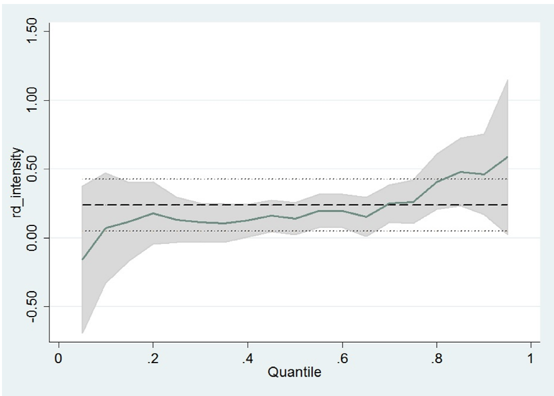
Figure 3. Quantile regression coefficient of R&D intensity in different industries (Sales Growth)



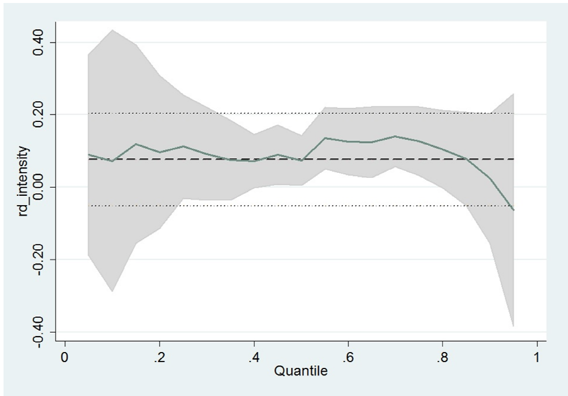
Low Tech Industry



Medium-low Tech Industry



Medium-high Tech Industry



High Tech Industry

Figure 4. Quantile regression coefficient of R&D intensity in different industries (Employment Growth)

5. Discussion

This study divided the concept of firm growth into two dimensions, sales growth and employment growth, and identified distinctions between the two in order to provide a more comprehensive understanding of the effect of R&D investment on firm growth. As far as sales growth is concerned, the result largely conformed to Coad and Rao (2008), thus confirming the significant positive effect of R&D investment on firm sales growth. Since the result was based on a large dataset—the Survey of Business Activities conducted by the Korea National Statistical Office—it provides empirical evidence that private R&D investment is essential for enterprise sales growth in Korea.

However, contrary results emerged for employment growth. According to the full-sample analysis using a panel fixed effect model, there was no significant effect of R&D investment on enterprise employment growth rate, an interesting result that previous studies such as Coad and Rao (2008) and Falk (2012) never identified.

To conduct more in-depth analysis of the discrepancy between the impact of R&D on sales growth and employment growth, this study investigated this discrepancy for each industry technology level group. The results revealed that the effect of R&D on sales growth was greater for high tech industries than for low tech industries whereas such tendency is not found when we analyze the effect of R&D on employment growth.

This result raises significant implications for government policy regarding R&D investment. Most importantly, R&D investment for high tech industries, such as IT, provides a technological opportunity for explosive sales growth but is not likely to lead to employment growth. That is, a policy cultivating high tech industries may, all else being equal, stimulate the emergence of several ultra-high growth firms but is less likely to achieve sustainable economic growth through employment growth.

More studies on the relationship between R&D investment and firm growth are required in the future. As this study suggests, future studies should endeavor to consider comprehensively the various effects of R&D investment for enhanced policy development.

References

BALCOMBE, K., BAILEY, A. & FRASER, I. 2005. Measuring the Impact of R&D on Productivity from a Econometric Time Series Perspective. *Journal of Productivity Analysis,* 24, 49-72.

COAD, A. & RAO, R. 2008. Innovation and firm growth in high-tech sectors: A quantile regression approach. *Research Policy,* 37, 633-648.

DE GEUS, A. 1997. THE Living COMPANY. (cover story). *Harvard Business Review,* 75, 51-59.

FALK, M. 2012. Quantile Estimates of the Impact of R&D Intensity on Firm Performance. *Small Business Economics,* 39, 19-37.

FRYXELL, G. E. 1990. Multiple Outcomes from Product R&D: Profitability Under Different Strategic Orientations. *Journal of Management,* 16, 633.

GARC A-MANJ N, J. V. & ROMERO-MERINO, M. E. 2012. Research, development, and firm growth. Empirical evidence from European top R&D spending firms. *Research Policy,* 41, 1084-1092.

GOLDBERG, S. R. & GODWIN, J. H. 2002. Business Darwinism -- Evolve or Dissolve: Adaptive Strategies for the Information Age/Business Expectations: Are You Using Technology to Its Fullest? *Journal of Corporate Accounting & Finance (Wiley),* 13, 63-65.

HATZICHRONOGLOU, T. 1997. *Revision of the High-Technology Sector and Product Classification*, OECD Publishing.

KOENKER, R. & BASSETT, G. 1978. Regression quantiles. *Econometrica*, 33-50.

ORTEGA-ARGILES, R., POTTERS, L. & VIVARELLI, M. 2011. R&D and Productivity: Testing Sectoral Peculiarities Using Micro Data. *Empirical Economics,* 41, 817-839.

WATANABE, C., YAMAUCHI, S., JAE-HO, S. & TOU, Y. 2009. FUSING "EAST AND WEST" FOR HIGH-PROFITABLE RESILIENT STRUCTURE IN MEGA-COMPETITION: A LESSON FROM SHIN-ETSU CHEMICAL'S GLOBAL CO-EVOLUTION STRATEGY. *Journal of Services Research,* 9, 123-151.

WU, C. & WEI, K. C. J. 1998. Cooperative R&D and the Value of the Firm. *Review of Industrial Organization,* 13, 425-446.

YUHONG, F. & CASE, F. M. 2010. EVIDENCE OF R&D EFFECTS ON CROSS SECTIONAL STOCK RETURNS. *Academy of Accounting & Financial Studies Journal,* 14, 31-41.