Research on the Impact of R&D Investment on Firm Performance in China's Internet of Things Industry

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***Abstract*—This paper uses 30 listed companies of the Internet of Things board in Shanghai and Shenzhen Stock Exchange as the research object, and collects the disclosed data in corporate annual reports from 2011 to 2013. Then we make an empirical study on the lag effect and the cumulative effect of R&D investment. We find, first, R&D investment has a non-significant impact on the current firm performance. Second, R&D investment has a positive impact on profit margin in the first lag phase, and the impact of the first lag phase is the most outstanding. Third, the cumulative effect of R&D investment has a negative correlation with firm performance. Finally, based on the results, this paper puts forwards some relevant policies for the related parties.**

***Index Terms*—R&D investment, firm performance, lag effect, cumulative effect, the Internet of things**

I. Introduction

The popularity and application of electronics and information technology has promoted the advent of the fifth scientific and technological revolution. With the development of Internet, the world has been stepping into another crucial cycle of technological innovation for half a century. Scientific and technological innovation becomes the theme of the fifth scientific and technological revolution, thereby innovation is bound to be a new driving force for economic growth. In February 2006, China's State Council issued the "*Planning on the Long-term Scientific and Technological Development*", specifying that the ratio of R&D investment to gross domestic product (GDP) will increase to 2.5% in 2020 and the government strives to build China into an innovation-oriented country in the next 15 to 20 years.

The Internet of Things is another innovative industry that depends on the computer, Internet and mobile communication network. The Internet of Things takes a crucial role in the promotion of social development, and is also one of seven strategic emerging industries in China. Nevertheless, there are still some problems on technological innovation, e.g. insufficient R&D investment, lack of innovative awareness, weak correlation between technological transformation and economic growth, etc. These seriously impede the technical innovations of China's Internet of Things industry. This paper aims to analyze 30 listed companies in the Internet of Things industry. Based on the study, we want to make some effective R&D strategies for enterprises to improve innovative awareness and core competitiveness.

II. Literature Review

Foreign scholars have made earlier studies on R&D investment and firm performance, and relevant theories and research results are relatively comprehensive. With respect to R&D investment and productivity, Griliches (1986) used the Cobb-Douglas production function to analyze R&D expenditure, sales revenue and employment of 1,000 manufacturing companies during 1957-1977. He found that there is a positive correlation between R&D expenditure and productivity [1]. Tsai and Wang (2004), collecting the data of 136 large manufacturing companies in Taiwan during 1994-2000, argued that R&D investment has a significant impact on business productivity, and R&D output effect in high-tech enterprises is larger than in traditional enterprises [2]. In terms of the impact of R&D investment on firm performance, based on the date of R&D expenditure in U.S. companies from 1976 to 1985, Morbey (1988) concluded that R&D expenditure has a great impact on sales revenue [3]. Using the same data, Sougiannis (1994) examined whether R&D investment could make a huge profit and the results show that 1 unit increase in R&D investment results in 2 units increase in corporate profits. Connolly (2005) also selected the U.S. companies in the 1997-2001 as a sample, and he suggested that R&D intensity has a continuously positive correlation with firm market value [4].

The domestic scholars have conducted a lot of researches on R&D investment and firm performance, however, they still hold different opinions. Most scholars believe that there is a significantly positive correlation between R&D investment on firm performance, while some think that there is no significant correlation.

Lu and Wang (2011) analyzed the impact of R&D investment on firm performance, the results indicated that there is a negative correlation between R&D and firm performance [5]. Zhou etc. (2011) investigated the

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influence of R&D investment on business profits of listed companies in Shanghai and Shenzhen Stock Exchange from 2002 to 2009. The results showed that R&D funding and staff input in each fiscal year can positive business profits, and the impacts of the first lag phase in R&D funding and the second lag phase in staff input are the most outstanding [6]. Liao (2013) pointed out that the relationship between R&D investment and firm performance is positive [7]. Zhao and Xu (2013), based on the panel date of 53 listed companies in the Yangtze Delta, found that R&D investment has a negative impact on the current profit margin and a positive impact on profit margin of the first lag phase, the second lag phase and the third lag phase [8].

We think the reasons that domestic scholars hold different opinions may be as follows. On the one hand, the samples may be variously selected. The samples that scholars selected are basically listed companies or some certain industries. The time span and research method may also lead to inconsistent results. On the other hand, the evaluation indicators may be different. The incomplete information disclosed by China's listed companies may restrict scholars to choose evaluation indicators. Therefore, examining the impact of R&D investment on firm performance in different industries is a viable option.

III. Research Design

A. Research Hypotheses

R&D investment aims to develop new products and new technology. When new technology is applied by the enterprise, it may increase the company's sales revenue and profits, expand market share, thereby enhance the core competitiveness of the products. Based on the relevant literature and previous research results, the hypotheses are proposed as follows.

H1: R&D investment can positive the current firm performance.

H2: R&D investment has a positive impact on the profit margin of the first and second lag phase.

H3: R&D investment has a positive impact on firm performance of the first and second cumulative phase.

B. Sample Selection and Data Collection

We selected 30 listed companies of the Internet of Things board as the research object and collected the disclosed information in the company's annual report during 2011-2013. Through rigorous screening, the companies that do not disclose R&D investment information are removed from the sample. The amount of companies selected is 30 in total.

C. Variable Definition

The ultimate goal of listed companies turns out to make profits. Therefore, the financial indicators measuring firm performance frequently tend to attract most investors. When studying the performance of R&D investment, we use profit margin as a dependent variable to measure the company's profitability.

Enterprises need a huge amount of funds and abundant manpower to support R&D investment. It is required by the China Securities Regulatory Commission that listed companies disclose the amount of R&D investment and the number of R&D personnel in annual report. We use R&D investment intensity and R&D personnel as independent variables.

In addition, the firm size and the asset-liability ratio may also affect firm performance. Therefore, we use corporate total assets and the asset-liability ratio as control variables

Table I shows the definition and description of the selected variables.

TABLE I. Variable Definition

Variable type	Variable	Definition
Dependent variable	OPE	Income from main operation to revenue of main business ratio (%)
	OUT	Revenue of main business
Independent variable	RD	R&D expenditure to sales ratio (%)
	TECH	The number of R&D personnel to the number of total employees ratio (%)
	CRD	R&D expenditure in 2013, R&D expenditure in 2012 and 2013, R&D expenditure during 2011-2013
Control variable	SIZE	Logarithm of the total assets
	DAR	Total liabilities to total assets (%)
	LABOR	Average number of employees during 2011-2013
	CAP	Average total assets during 2011 to 2013

D. Model

This paper builds the multiple linear regression models to explore the correlation between the R&D investment and firm performance as well as the lag effect. Cobb-Douglas production function is applied to analyze the cumulative effect of R&D investment.

Model (1) aims to examine the correlation between R&D investment and current firm performance.

$$OPE = \beta_0 + \beta_1 RD + \beta_2 TECH + \beta_3 LnSIZE + \beta_4 DAR + \varepsilon_i \quad (1)$$

where β_0, β_1, β_2, β_3, β_4, respectively, denote presumed parameters; ε_i represents the error item.

Model (2) aims to examine the correlation between R&D investment and the lag effect of firm performance.

$$OPE_t = \beta_0 + \beta_1 RD_{t-h} + \beta_2 TECH_{t-j} + \beta_3 LnSIZE_t + \beta_4 DAR_t + \varepsilon_i \quad (2)$$

where β_0, β_1, β_2, β_3, β_4, respectively, denote presumed parameters; ε_i, the error item; t, the time period.

Model (3) is used to test the impact of R&D investment on the cumulative effect of firm performance.

$$LnOUT_t = A + \alpha LnCRD_t + \beta LnLABOR_t + \gamma LnCAP_t + \varepsilon_i, [t=1, 2, 3] \quad (3)$$

where A, α, β, γ, respectively, represent presumed parameters; ε_i, the error item; t, the time period.

IV. Empirical Results

A. Descriptive Statistical Analysis

According to the analysis of the data, Table II shows the statistical characteristics of the sample.

TABLE II. Descriptive Statistics of R&D Investment Intensity (from 2011 to 2013)

Year	Min	Max	Mean	SD
2011	0.000227	0.290669	0.067535	0.003615
2012	0.000695	0.368605	0.074313	0.005004
2013	0.000879	0.398410	0.073380	0.005337

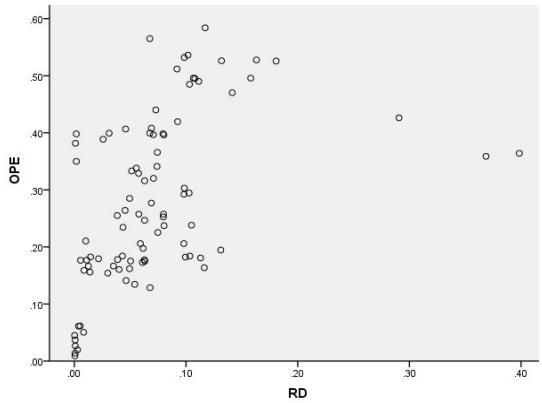

Figure 1. The scatterplot of R&D intensity and profit margin of 30 listed companies from 2011 to 2013.

Figure 2. The trend of average R&D intensity and average profit margin from 2011 to 2013.

From Table II, Fig. 1 and Fig. 2, we can conclude that the proportion of R&D investment in China's Internet of Things industry is gradually increasing. It is generally believed that a firm with more than 2% of R&D investment intensity may continue to obtain a sustainable growth, and more than 5% of R&D investment intensity may enable the company to gain core competitiveness. We also can find that the innovative awareness is constantly raised. Meanwhile, the line chart shows that there is an inverse relationship between the average profit margin and the average R&D intensity, which indicates that corporate R&D investment in China's Internet of Things industry cannot economically promote corporate profits. The major reasons are that corporate R&D investment is a long process and it takes some tome to bring economic benefits, that is, R&D investment has the lag effect. The average profit margin declines from 2011 to 2013, indicating that business profitability and corporate competitiveness has a downward trend.

B. The Effect of R&D Investment on Current Firm Performance

We use the multiple linear regression method to test the relationship between R&D investment and firm performance based on the data of the Internet of Things enterprises from 2011 to 2013. The results are shown in Table III.

TABLE III. The Estimation Results of the Effect of R&D Investment on Current Firm Performance

Year	2011	2012	2013
Constant	0.345	0.298	0.303
	(0.962)	(0.809)	(0.793)
RD	0.820*	0.585	0.414
	(1.766)	(1.588)	(1.033)
TECH	0.011	-0.053	0.020
	(0.076)	(-0.390)	(0.126)
LnSIZE	0.001	0.004	0.002
	(0.042)	(0.242)	(0.126)
DAR	-0.326***	-0.347*	-0.270**
	(-2.951)	(-2.805)	(-2.096)
Adj. R sq	0.420	0.336	0.214
F	6.250***	4.673***	2.972**

Note：t-values are in parenthese, *** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level.

It is more appropriate to use model (1) to test the impact of R&D investment on current firm performance. The model in 2011, 2012 and 2013 are all at the significant level of 5%, indicating that model (1) shows a good fit.

According to Table II, the coefficient of RD is respectively 0.820, 0.585 and 0.414, and not at the significant level of 5%, which means that the R&D investment has non-significantly positive effects on current firm performance. Therefore, hypothesis 1 is not fully supported. The competition in the Internet of Things industry is increasingly fierce without effective trade barriers, which leads to the decline of company's profitability. Simultaneously, it can be found that the amount of R&D personnel and firm size has non-significant impacts on current firm performance. However,

it can also be found that the asset-liability ratio has significantly negative effects on current firm performance, and all at the significant level of 1%. The coefficient is -0.326, -0.347 and -0.270, respectively.

C. The Lag Effect of R&D Investment on Firm Performance

Table IV shows the estimation results of the lag effect of R&D investment on firm performance.

TABLE IV. THE ESTIMATION RESULTS OF THE LAG EFFECT OF R&D INVESTMENT

	The current lag phase	The first lag phase	The second lag phase
Constant	0.322	0.255	0.221
	(1.593)	(1.017)	(0.594)
RD	0.565***	0.582***	0.569
	(2.557)	(2.037)	(1.150)
TECH	-0.005	0.004	0.072
	(-0.065)	(0.044)	(0.477)
LnSIZE	0.002	0.005	0.005
	(0.235)	(0.393)	(0.266)
DAR	-0.317***	-0.300***	-0.259**
	(-4.811)	(-3.593)	(-2.103)
Adj. R sq	0.382	0.334	0.247
F	14.757**	8.412***	3.384***

Note：t-values are in parenthese, *** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level.

The model (2) in the three lag phases all reach the significant level of 5%, which means that model (2) also shows a good fit. According to Table IV, the coefficient of RD in the current and the first lag phase is 0.582 and 0.565, respectively, and both significant at the 5% level. This means that in the enterprises, the R&D investment increased by 1%, the profit margin in the current year and next year will grow by 0.565% and 0.582%, respectively. The Internet of Things industry mainly focuses on the exchange and processing of information, but the investment tends to depreciate very fast and the core technology is easy to be imitated by rivals, which makes the decline of profitability in the lag phases.

However，the labor investment and the size of the enterprises has non-significant effects on firm performance in the lag phase. Unlike the labor investment and firm size, the asset-liability ratio has significantly negative effects on firm performance. The absolute value of the coefficient of DAR shows a downward trend, indicating that the higher the asset-liability ratio, the lower the profit margin. Moreover, the impact of the asset-liability ratio is gradually weakening.

D. The Analysis of the Cumulative Effect of R&D Investment

Table V shows the estimation results of the cumulative effect of R&D investment.

From Table V, model (3) is all significant at the level of 1%, indicating that it is appropriate to use model (3) to analyze R&D cumulative effect on firm performance.

TABLE V. THE ESTIMATION RESULTS OF THE CUMULATIVE EFFECT OF R&D INVESTMENT

	1-year cumulative effect	2-year cumulative effect	3-year cumulative effect
Constant	9.534***	9.691***	10.126***
	(3.591)	(3.686)	(3.880)
LnCRD	-0.315*	-0.314**	-0.341**
	(-1.893)	(-2.053)	(-2.337)
LnLABOR	0.816***	0.826***	0.837***
	(5.998)	(6.106)	(6.300)
LnCAP	0.520**	0.517**	0.521***
	(3.176)	(3.255)	(3.402)
Adj. R sq	0.834	0.838	0.844
F	49.706***	50.954***	53.414***

Note：t-values are in parenthese, *** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level.

The coefficient of cumulative R&D investment in two years and three years is -0.314 and -0.341, respectively, and both significant at the level of 5%. It represents that cumulative R&D investment has negative effects on firm performance and cumulative R&D investment increased by 1%, profit margin will decrease by about 0.3%. Therefore, the hypothesis 3 should be rejected. Meanwhile, labor investment is also significant correlations (at the level of 1%) with firm performance, the coefficient is 0.816, 0.826 and 0.837, respectively, which indicates that one unit increase in labor investment can promote 0.8 unit increase in profit margin. The coefficient of capital investment is very significant (at the 5% level) and stable, fluctuating around 0.520. Labor investment has larger effects than capital investment.

V. CONCLUSIONS AND IMPLICATIONS

The purpose of this study is to analyze the relationship of R&D investment and firm performance. The main conclusions are summarized below. First, R&D investment in the Internet of Things industry has non-significant effects on current firm performance; labor investment also has non-significant effects on firm performance; capital structure has a negative correlation with firm performance. Second, there is a positive relationship between R&D investment and profit margin in the current and next year. Third, cumulative R&D investment has a negative influence on firm performance, while labor investment and capital investment a greater positive effect.

We draw three implications from our findings.

First, as for enterprises, on the one hand, managers encourage innovation and make deeper researches on technical innovation in order to improve their core competitiveness. On the other hand, companies should set long-term development strategies and continue to make

R&D investments because it takes some time to apply the latest technology into the product manufacturing. Therefore, on the basis of a reasonable capital structure, enterprises should use multiple financing methods to increase R&D investments.

Research and development may be categorized into three activities, i.e. basic research, applied research and experimental research. Basic research is not only the foundation of R&D inputs, but the source of innovation and creation [9]. The empirical results show that the cumulative effects of R&D inputs are unfavorable. Therefore, enterprises in the Internet of Things industry should provide abundant funds for basic research to ensure the results of basic research can effectively support the applied research and experimental research.

Finally, local governments should introduce some appropriate policies backed with financial or tax incentives to stimulate business R&D investment and conduct scientific research [10]. As for the countries, comprehensive laws and regulations related to intellectual property should be established to ensure innovative patents will not be illegally used by individuals and other organizations. In addition, the government ought to improve the financing environment and provide adequate financial supports for business R&D investment.

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