温州肯恩大学
WENZHOU-KEAN UNIVERSITY

Research and development intensity and the performance of Chinese high-and new-technology enterprises

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ZHOU Heran

1026024

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ABSTRACT

Using R&D expenditure data from Chinese listed high-and new-technology enterprises, this paper examines the relationship between R&D intensity and firm performance in both short term and long term. The finding presents that R&D intensity worsens the current firm profitability and only insignificantly contributes to the long-term firm valuation. The result further shows that, during the lag period from one to three years, lagged R&D has an increasingly favorable effect on firm performance as the extension of the lag period. In Chinese high-and new-technology industries, it takes approximately two years for R&D expenditure to explicitly optimize the firm performance. The overall results offer an implication for corporate managers to implement informed R&D time management and maximize the value of R&D investment.

Keywords*:* R&D intensity; firm performance; lag effect; Chinese high-and new-technology industry.

JEL Classifications: O32, M41.

I. INTRODUCTION

This paper studies the link between research and development (R&D) intensity and firm performance of the Chinese high-and new-technology industries in both the short term and long term. As a means to generate innovative products or services and to develop advanced technology, R&D expenditure is recognized as an indicator of firm innovation ability, which is essential to firms' competitiveness and profitability. Previous literature has explored the association between R&D intensity and firm performance measured by firm productivity, profitability, and long-term market valuation (Jaffe 1986; Griliches 1982; Mansfield 1980; Klette 1996; Guo et al. 2004; Vithessonthi and Racela 2016). Despite the recognition that R&D ultimately generates competitive advantages for firms, R&D faces a series of complicated problems about the methods of capitalization and the risk of returns on R&D investment. The uncertainty of R&D effectiveness causes the inconsistency of the relationship between R&D and firm performance under different circumstances. This relationship commonly varies from different performance indicators, periods, regions, and industries (Griliches 1982; Guo et al. 2004; Ayadi et al. 1996; Yeh et al. 2010; Xiao 2013; Xu and Jin 2016). Under this circumstance, firms should attach importance to this variation to make informed R&D decisions.

R&D effectiveness is complicated and uncertain because it is difficult to guarantee a high conversion rate from R&D expenses to firm value (Hollanders and Celikel-Esser 2007). A common assumption is that the amount and quality of R&D outputs cannot match the size of R&D inputs in the short run. This phenomenon could be explained by the R&D lag effect, which means R&D cannot take favorable effects in the short term, but it works as the changes in time, resources, environment, etc. (Garud and Nayyar 1994). Prior studies present that the R&D lag period may vary from years, industries, and regions to optimize firm performance (Parasuraman and Zeren

1983; Guan and Chen 2010; Yeh et.al 2010; Campbell 2012). Hence, the length of a lag period should not be overlooked in both empirical analysis and practical activities. Empirically, the lag period should be incorporated into R&D to get significant and effective results. Practically, the R&D lag period could guide corporate managers to make informed R&D investment decisions, assessments, and forecasts.

With the enhancement of international competitiveness, China has greatly encouraged the founding of high-tech firms and the investment in industrial R&D. Correspondingly, from the accounting perspective, the growing number of R&D-related transactions suggests that companies should follow the standard, reasonable, and improved R&D rules to ensure the accurate disclosure of firm performance. Nowadays, in China, the accounting standards for R&D are regulated by the Ministry of Finance of People's Republic of China (ASBE 6, 2007). The standard states that R&D expenditures in the development phase can be capitalized, provided multiple conditions are met[1]. Firms are allowed to capitalize their feasible, completed R&D to the balance sheet for the adjustment of their firm value. However, this regulation still infers the complication of R&D capitalization, because it cannot avoid the problem of data manipulation. in this way, firms are still possible to distort the intangible assets for the benefit of favorable records presented by the financial statement. Thus, the recorded R&D expenditures cannot directly and wholly enhance firm performance. It is necessary to test the effectiveness of recorded R&D expenditure towards the firm performance, especially in high-and new-technology enterprises, which rely heavily on R&D to generate profits and competitiveness. Overall, the purpose of this study is to investigate

[1] According to ASBE 6: Intangible Assets, article 9, the conditions are (1) it is technically feasible to finish intangible assets for use or sale; (2) it is intended to finish and use or sell; (3) the usefulness of methods for intangible assets to generate economic benefits shall be proved; (4) adequate technical and financial resources are available to complete the development of intangible assets; and (5) the development expenditure can be separately and reliably measured.

whether R&D in research-intensive firms has different effects on short-term performance and long-term performance and whether the previous R&D investment will take stronger, more evident effects after the lag periods than that in the current period. Then, through analyzing how the relationship changes across years, this study aims to figure out a suitable R&D lag period of the Chinese high-and new-technology industries in the recent decade for the benefit of their R&D time management and evaluation.

The empirical results show that considering 490 Chinese high-and new-technology firms from 2007 to 2016, R&D intensity is negative to the current firm performance measured by return on asset (ROA) and insignificantly contributes to the long-term performance measured by Tobin's Q. The short-term test with ROA has the same result as prior studies. However, the long-term empirical result is inconsistent with most studies that use Tobin's Q as a long-term firm performance proxy. This deviation encourages further tests for the effectiveness of market value in the Chinese stock market and the moderating effect between R&D and other influence factors. Then, from the perspective of difference in short-term and long-term tests, this study involves lag effects from one-to-three lag years in R&D intensity. The findings present that the negative effect of R&D on short-term performance progressively reduces as the extension of the lag period. Correspondingly, the contribution to firm value strengthens to some extent as the increase of the lag period. Overall, the tendency supports Guan and Chen (2010) that the lag period for R&D to take significant, maximum effects is about two years in the Chinese research-intensive and high-tech industries.

This paper contributes to previous literature (1) by testing the effectiveness of firm performance measures that represent the short-term and long-term performance and (2) by identifying the appropriate time lag period in Chinese high-and new-technology industries to provide a better understanding for managers in corporate R&D control. Firstly, the empirical evidence of a negative association between R&D intensity and ROA is consistent with prior research (Ayadi et al. 1996; Vithessonthi and Racela 2016). It supports that the capitalization of R&D is not conducive to favorable short-term firm performance. Whereas, the insignificant result between R&D and Tobin's Q represents that the market value, or Tobin's Q, is inefficient as the long-term performance indicator in the Chinese stock market, in line with the empirical evidence from Xiong and Yu (2011) and Guo et al. (2018). Also, indicating that R&D intensity cannot work solely to contribute to long-term firm performance, this paper enlightens further studies to focus on other elements that would interact with R&D to contribute collectively to the long-term firm performance. Secondly, the complication of R&D effectiveness suggests that the R&D lag period varies from years, regions, industries, and etc. This paper concludes a two-year R&D lag period that significantly optimizes the firm performance in the Chinese high-and new-technology industries. This predicted R&D lag period offers managers a better comprehension of the R&D time lag effect when they plan for the R&D budget and evaluate how firm profitability and valuation have been influenced by R&D expenditures.

The remainder of this paper progresses as follows. Section II reviews the literature related to R&D, firm performance, and lag effects. This section mainly discusses the inconsistent findings of the R&D effectiveness from the time perspective. Three hypotheses are developed according to the disagreement among prior studies. Section III describes the research methodology, testing model, and each variable in the empirical tests. Section IV presents the sample description and empirical results and findings. Section V draws a conclusion based on research questions and findings. Further, this section discusses the limitations of this study.

II. LITERATURE REVIEW

R&D investment is described as a process that contributes to the innovation function of firms and increases firm value by creating knowledge stock and competitive advantages (Drucker 2007; Jaffe 1986). The scientific discoveries and technical knowledge generated by R&D can be converted into the development of products, services, and corporate strategies, which impact firms' current and future performance collectively (Vithessonthi and Racela 2016). Particularly, R&D plays an important role in research-intensive firms, where the innovation developing and profit generation heavily rely on the completed, feasible R&D investment. With R&D activities taking up a growing proportion of firms' day-to-day operations, R&D intensity has become a critical factor for the business success.

A large number of previous studies have investigated the R&D intensity on firm performance including operating performance, productivity, profitability, and solvency. Some of them present significant and positive empirical results of the relationship between R&D intensity and firm performance indicated by different financial measures. Griliches (1979) proposes the Cobb-Douglas production function model to estimate the relationship between R&D expenditures and firm production. This model is applied by researchers in different periods and regions to conclude that R&D intensity is positively and significantly related to the growth of productivity (Griliches 1982; Mansfield 1980; Klette 1996). Moreover, the market growth rate, competitive structure, firm size, debt-to-asset ratio, fixed asset ratio, and R&D personnel proportion are taken into consideration to measure the firm performance. The results demonstrate that R&D expenditures promote the firm performance of high-tech enterprises in the U.S, Japan, China and etc. (Lee and Shim 1995; Falk 2010; Xu and Jin 2016; Vithessonthi and Racela 2016; Xiao, et al. 2013). These empirical relationships represent that R&D contributes to firm performance in many aspects. Increasing R&D expenditure is a way to promote the development of firms. Despite the favorable effects shown in many studies, others point out that R&D expenditures can also cause a negative or insignificant R&D-firm performance relationship and unfavorable firm performance. Ayadi et al. (1996) reveal a negative effect on short-term profitability. Xu and Jin (2016) state that R&D does not have a significant relationship with short-term firm performance. Lin et al. (2006) show that R&D expenditure is insignificant to Tobin's Q. The inconsistency among positive, negative, and insignificant effects implies that, in order to obtain a comprehensive result, the firm performance measures should be categorized according to their functions and effectiveness. In other words, indicators representing short-term performance should be measured separately from long-term performance indicators.

Some studies have explored deeply the timing effect on R&D effectiveness. Their empirical results have considered the difference between short-term and long-term performance, and they emphasize that R&D cannot have merely one type of effect in the R&D life cycle (Ayadi et al. 1996; Guo et al. 2004; Yeh et al. 2010; Vithessonthi and Racela 2016). Either positive or negative correlation is possible when the R&D-firm performance relationship is measured by different indicators concerning timing classification. To be specific, the majority of studies use return on asset (ROA), return on equity (ROE), return on sales (ROS), or return on investment (ROI) to measure short-term returns and firm profitability. Additionally, they use the market value, Tobin's Q, or book-to-market ratio to measure the long-term performance and firm value. Most results indicate that the R&D level is positively associated with the long-term performance proxies, but it is negatively related to these short-term proxies (Griliches 1981; Ayadi et al. 1996; Guo et al. 2004; Vithessonthi and Racela 2016).

However, regarding the R&D-firm performance relationship in the context of China, few studies focus on the different effects in the short-term and long-term performance. Xu and Jin's (2016) findings are more supportive of the results from the majority of studies. They conclude that R&D intensity in the Chinese IoT industry is positive to the profit margin in the long run but is insignificant to current performance. While, others do not have consistent results. Guo et al. (2010) conclude that there is a positive relationship between R&D and ROA, ROE. A larger deviation is shown in Xiao (2013) whose study disagrees with the difference in firm performance across time and claims that no matter it is in the short run or the long run, measured by ROA and ROS, the higher R&D intensity, the better the performance of Chinese firms.

The inconsistency of the above results could be explained by the difference in time, industries, regions, and other conditional limits. With the growing importance of R&D to the competitive advantages and innovation ability, R&D expenditures and intensity may lead to more complex results in recent years. Focusing on China, the deviation existing in prior studies encourages researchers to further investigate the R&D effectiveness in China. Thus, in this paper, the first two hypotheses are proposed to test the relationship between R&D intensity and firm performance measured in both the short term and long term. The assumption is based on the results of most studies that R&D does not promote current performance but is in favor of long-term performance. Especially, those hypotheses are aimed at checking how R&D affects the Chinese research-intensive firms from the time perspective.

H1*: R&D intensity is negatively associated with current firm performance.*

H2*: R&D intensity is positively associated with long-term firm performance.*

Then, regarding the complicated performance of R&D expenditures, prior studies have further explored factors that may affect the R&D efficiency, for example, lag effects (R&D

expenditures take effects after a certain period) and moderating effects (R&D expenditures work with other factors to contribute to firm performance) (Lin et al. 2006; Campbell 2012; Vithessonthi and Racela 2016). To measure R&D efficiency, firms should quantify the R&D performance and track both conversion time and progress rate that allows the R&D inputs, including R&D expenditure and R&D labors, convert to the R&D outputs including competitive advantages and profit generation (Hollanders and Celikel-Esser 2007). In this conversion process, the R&D lag effect may address the problem that R&D is unfavorable to current firm performance but contributes it in the long run.

The lag effect illustrates the phenomenon that expenditures in R&D cannot take effect immediately but become competitive with the change in the organizational environment (Sorensen and Stuart 2000), reconstruction of corporate structure, the accumulation of internal and external resources, or new business opportunities (Garud and Nayyar 1994). The complicated situation indicates that past expenditure may have various, strength effects on future innovation. In other words, because of the time lag effects, R&D is more likely to promote knowledge generation and firm performance in a certain period after the incurrence of expenditures (Garud and Nayyar 1994; Wang and Hagedoorn 2014). The performance of the Chinese high-and new-technology industries supports this viewpoint. Tested by the data envelopment analysis (DEA) model, the operation of the R&D system is not efficient in the first five years after the enactment of the National Plan for Medium-and long-term Scientific and Technological Development (Chen, et al. 2018). Han, et al. (2017) also concludes that the current improvement of R&D efficiency has not matched the continuous increase in R&D inputs. Hence, without figuring out the explicit R&D lag period, it is difficult for managers to estimate the R&D conversion efficiency and plan for the R&D investment and return (Hall and Mairesse 1995).

There are three main difficulties in the estimation of lag period: firstly, criteria of the lag period selection are influenced by the industry difference that distinguishes the R&D level; secondly, the length of lag period is sensitive to the business practice in different periods (Yeh et al. 2010); thirdly, a pre-specified, definite lag structure is probably inaccurate and misleading to explain all plausible alternatives in R&D effectiveness (Ravenscraft and Scherer 1982). With the difficulties, although some prior studies attach importance to the R&D lag effect, they have no universally accepted lag period because firms in different periods, geographical regions, and industries have different transformative capacities to convert R&D expenditures to knowledge production (Garud and Nayyar 1994).

Previous literature describes various R&D lag period. Ravenscraft and Scherer (1982) use the binominal approach to estimate a four-to six-year lag period of R&D programs in the 1970s. Suzuki (1985) shows that the average lag period varies from 2.1 years to 3.7 years among Japanese technological manufacturing industries. Parasuraman and Zeren (1983) present that, computed by average correlation coefficients method to test the year with the highest correlation between R&D and firm performance, the two- or the three-year lagged effect is also proved in high-tech industries such as aerospace and electronics. Guan and Chen's (2010) empirical analysis presents that a two-year lag period should be considered for the R&D process in Chinese high-tech innovation activities. Whereas, Hollanders and Celikel-Esser (2007) conclude that the lag period has little effect on the R&D efficiency estimation. The conflicted fact suggests that it is arbitrary to determine a fixed, long-lasting lag period because of the risky, uncertain R&D activities (Pavitt 1990, Yeh et al. 2010). While, in reaction to the disagreement among the length of lag period, research-intensive firms are recommended to figure out a relatively explicit lag period for specific industries within a certain period for an optimal R&D decision.

Hence, according to the previous studies, the time lag effect is appropriate to be considered a linkage between R&D investment and its efficiency (Chen, et al. 2018) and a tool to evaluate R&D effectiveness as well. Overall, this study raises the third hypothesis that R&D lag periods could match the difference in the short-term and long-term effectiveness of R&D investment. This hypothesis could explain how the extension of the R&D lag period affects the changes in firm performance.

***H3**: R&D expenditure has the lag effect to delay the favorable current firm performance and promote firm performance after lag periods.*

III. RESEARCH METHODOLOGY

The examination of R&D effects is usually expressed by multiple regression analysis that assumes a linear relationship between R&D intensity and measures of firm performance (Griliches 1982; Lee and Shim 1995; Ayadi et al. 1996; Guo et al. 2004; Xu and Jin 2016; Vithessonthi and Racela 2016). This study adopts the ordinary least square (OLS) regression model to test the three hypotheses about the relationship between R&D intensity and firm performance. Firstly, to test the fundamental association between variables for the first two hypotheses, this model is applied to test the R&D-firm performance relationship happening in the same fiscal year, without lag R&D intensity. Then, this paper conducts a multiyear analysis. The lag effect from one-to-three years is incorporated into R&D intensity to examine the change tendency of R&D-firm performance relationship and its change tendency as the extension of the lag period. The basic model for this study is shown as follow:

$$PERF_{it} = \beta_0 + \beta_1 RDI_{it-n} + \beta_2 SIZE_{it} + \beta_3 LEV_{it} + \beta_4 FAR_{it} + YEAR + IND + \varepsilon_{it} \quad (1)$$

Where $PERF_{it}$, the dependent variable, represents the proxy indicators of firm performance – return on asset (ROA) and Tobin's Q in the first two tests - for the firm *i* in year *t-n*. *n=0* is applied to investigate the effect of current R&D expenditures on firm performance without the R&D lag effect. *n=1,2,3*, denoting R&D in previous *n* years, is applied to test the relationship with the R&D lag effect. ROA measures firm profitability and short-term return, but it is a poor indicator for future performance prediction (Cui and Mak 2002; Vithessonthi and Racela 2016). Tobin's Q, defined as the ratio of market value to book value of a firm, is an alternative measure of the firm value and long-term firm performance (Chung and Pruitt 1994). However, Guo (2018) indicates that Tobin's Q is ineffective in the Chinese stock market because of the operation of traders and political policy. Thus, the effectiveness of Tobin's Q will be tested in this analysis. For independent variables, *RDI*, denoting the R&D intensity, is the explanatory variable of this study. It is expressed by the R&D expenditures scaled by the total sales of companies. It is well-accepted as the index of R&D strategic use and innovation capability (Parasuraman and Zeren 1983; Cui and Mak 2002; Guo et al. 2004; Yeh et al. 2010; Vithessonthi and Racela 2016).

To isolate the inside- and outside-company effects on firm performance and derive accurate analysis results, this paper follows prior studies to incorporate five control variables including $SIZE_{it}$, the firm size, LEV_{it}, the leverage ratio, FAR_{it}, the fixed assets ratio, *YEAR*, the year effect, and *IND*, the industry effect into the testing model (Cui and Mak 2002; Vithessonthi and Racela 2016). Firstly, firm size is expressed by the natural logarithm of total assets. The firm size has long been considered an element that contributes to the innovation ability of firms (Lin and Chen 2005). Large firms are relatively easy to take R&D into effects, but they have lower flexibility to confront the structure or budgeting changes within organizations (Campbell 2012). The leverage ratio should be controlled because it is an important fact in the firm capital structure to generate profit for companies (Yeh et al 2010). The fixed asset ratio concerns the proportion of fixed assets relative to the total assets, affecting how fixed assets have an influence over the profit generation (Vithessonthi and Racela 2016). Then, this paper controls the fixed effect of dummy variables, YEAR and IND. This process excludes the effect that past firm performance may have on future performance and the effect that may show up in a specific industry. β_0 is a constant parameter. The standard error, ε_{it}, considers the random, unexplained variables contributing to the proxy of firm performance.

Then, for the lag effect of R&D expenditures on the firm performance, instead of incorporating all lagged R&D variables in one model, this study involves several sets of tests for different lag periods to avoid the multicollinearity problem. $n=1, 2, 3$ is applied in turn in different tests to denote the R&D lag effect. This multiyear linear regression is supported by Ravenscraft and Scherer (1982), Mahmood and Mann (2005), and Campbell (2012) to analyze the change tendency across years. For the selection of testing period, considering that Parasuraman and Zeren (1983), Guan and Chen (2010) and Campbell (2012) support a two-to-three-year lag period in research-intensive industries, this study applies the lagged R&D with one-, two-, and three-year lag period denoted by RDI_{it-1}, RDI_{it-2}, and RDI_{it-3} to examine whether the R&D expenditure would delay or worsen the current performance but have favorable, stronger effects after the lag period. Following the analysis process of Mahmood and Mann (2005) and Campbell (2012), the coefficients of RDI in each lag period test will be compared to investigate the tendency of R&D-firm performance relationship as the extension of the lag period. In this way, it is clear for researchers to point out the length of lag period that has relatively satisfying and significant effects to maximize R&D effectiveness.

IV. EMPIRICAL RESULTS

The observations of Chinese-listed firms are acquired from the China Stock Market and Accounting Research (CSMAR) database. Since CSMAR contains the data of R&D expenditures only from 2007 to 2016, the sample of this study covers this ten-year period (2007-2016). Considering the importance of R&D expenditures in firms, this study is targeted at the high-and new-technology firms, where R&D expenditure has a crucial function in the generation of competitive advantages and revenues. The industry selection is based on the classification from the China Statistics Yearbook on High Technology Industry and the China Securities Regulatory Commission (CSRC) industry classification. All selected firms are distinguished by 3-digit 2012 CSRC industry code. Details of the categories are explained in the Appendices. Then, to eliminate the repetitive effect and make observations comparable, this study restricts the financial statement type to the consolidated financial statement and keeps records that use December 31 as the ending date of the fascial year. Finally, since the research questions mainly focus on R&D, records with missing R&D expenditures are excluded. The final sample includes 490 firms with 2344 firm-year observations.

The sample firms include the Chinese listed high-and new technology-related firms from the fields of manufacturing, information technology, and environmental treatment. For the year distribution, the number of high-technology firms is increasing progressively over the sample period. The number of sample firms is 77 in 2007 and quickly quintuples to 389 in 2016. This growth is reasonable to represent a fast expansion of the Chinese high-and new-technology industries.

Table 1 summarizes each variable that is used in empirical tests. The mean value of ROA and Tobin's Q are 5.219% and 3.488 respectively. The R&D Intensity (RDI) has a mean of 0.084, with a range from 0.000 to 1.872. The sample has an average firm size of 21.758, leverage ratio of 0.366, and fixed asset ratio of 0.166. The lagged variables present that, for the one-year lag period, the sample mean of RDI is 0.034, with a range from 0.000 to 1.235. For the two-year lag period, the sample mean of RDI is 0.033, with a range from 0.000 to 1.235. For the three-year lag period, the sample mean of RDI is 0.032, with a range from 0.000 to 1.198. Overall, the results of the computation are associated with the tendency in prior research. The detailed variable definition and description are included in Appendices.

Table 1 Statistics Summary

Variables	No. of obs.	Mean	Std	Max	Min	25% Percentile	Median	75% Percentile
ROA (%)	2211	5.219	0.058	46.311	-32.161	1.936	4.525	8.048
Tobin's Q	2202	3.488	2.540	29.277	0.219	1.940	2.758	4.161
RDI_t	2344	0.034	0.084	1.872	0.000	0.004	0.013	0.034
SIZE	2344	21.758	1.134	26.547	18.721	20.915	21.670	22.379
LEV	2344	0.366	0.205	1.352	0.008	0.199	0.349	0.512
FAR	2344	0.166	0.110	0.789	0.001	0.082	0.144	0.230
RDI_{t-1}	1854	0.034	0.078	1.235	0.000	0.005	0.014	0.035
RDI_{t-2}	1441	0.033	0.078	1.235	0.000	0.005	0.014	0.035
RDI_{t-3}	1099	0.032	0.074	1.198	0.000	0.004	0.014	0.034

ROA (return on assets) and Tobin's Q represent short-term and long-term firm performance respectively. RDI_t is R&D intensity computed by R&D expenditure to total sales of company. SIZE is the firm size concerning the firm total asset. LEV is leverage ratio concerning the firm liability level. FAR is fixed asset ratio that measures the proportion of fixed assets. RDI_{t-1}, RDI_{t-2}, and RDI_{t-3}, representing R&D intensity with one-, two-, and three-year lag. Lagged variables share the same data source. Further details of all variables are shown in Appendices.

Table 2 reports the pairwise correlation coefficient for every two variables in this empirical test. Except for lagged variables such as RDI_t, RDI_{t-1}, RDI_{t-2}, and RDI_{t-3}, the absolute values of correlation coefficients between variables are below 0.5. Thus, multicollinearity is not significant in this empirical test in line with Ravenscraft and Scherer (1982). The correlation coefficient between lagged variables is closed to 1 because they share the same data source, and these lagged variables are entered separately to different regression tests to avoid multicollinearity.

Table 2 Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) ROA	1.000								
(2) TBQ	0.295***	1.000							
(3) RDI_t	-0.053**	0.091***	1.000						
(4) SIZE	-0.020	-0.363***	-0.099***	1.000					
(5) LEV	-0.361***	-0.326***	-0.132***	0.483***	1.000				
(6) FAR	-0.153***	-0.158***	-0.075***	0.047**	0.231***	1.000			
(7) RDI_{t-1}	-0.070***	0.119***	0.822***	-0.120***	-0.141***	-0.088***	1.000		
(8) RDI_{t-2}	-0.050*	0.127***	0.666***	-0.126***	-0.144***	-0.103***	0.813***	1.000	
(9) RDI_{t-3}	-0.027	0.166***	0.404***	-0.140***	-0.148***	-0.126***	0.580***	0.818***	1.000

*** p<0.01, ** p<0.05, * p<0.1. All variables are described in detail in Appendices.

Table 3 presents the OLS regression analysis of R&D intensity and firm performance in both short term and long term, measured by ROA and Tobin's Q separately. The results indicate that in Model (1), R&D intensity (RDI) is negatively associated with ROA (CO=-0.061, $p<0.01$), consistent with Guo et al. (2018) and Ayadi et al. (1996). It supports the hypothesis H1 that R&D intensity is negatively associated with the current firm performance. While, in Model (2) in the long-term performance test, RDI is insignificant to Tobin's Q (CO=0.643, $p>0.1$). It is contradicted to the hypothesis H2 that R&D intensity is significantly positive to long-term firm performance. Additionally, it is inconsistent with Griliches (1981), Ayadi et al. (1996), and Vithessonthi and Racela (2016). But the result is in line with Lin, et al. (2006) and Guo et al. (2018) to show an insignificant relationship. Lin, et al. (2006) explains that the insignificance is reasonable because the competitive advantages cannot be improved solely by R&D intensity, and they emphasize that the interactive and moderating effect of R&D should not be ignored. In other words, to significantly benefit the long-term firm valuation, R&D should work with other elements that affect firm performance. Guo et al. (2018) give another explanation that Tobin's Q is inefficient in the Chinese stock market because the market value is distorted by the noise of traders and the interruption of political policies.

For control effects, the firm size (SIZE) is significantly positive to ROA, but significantly negative to Tobin's Q. The leverage ratio (LEV) and fixed asset ratio (FAR) have a significantly negative coefficient for ROA and Tobin's Q. Concerning both tests, although the results deviate to the hypotheses to some extent, an obvious trend implies that R&D expenditures take different effects in short term and long term measures. To be specific, R&D expenditures would take a certain period to create competitive advantages for companies. This finding encourages the lag effect test for R&D expenditures and its reasonable lag period to maximize firm performance.

Table 3 Regression Analysis of Firm Performance

VARIABLES	(1) ROA	(2) Tobin's Q
RDI	-0.061***	0.643
	(-4.769)	(0.955)
SIZE	0.011***	-0.823***
	(8.653)	(-15.907)
LEV	-0.126***	-1.566***
	(-16.843)	(-6.139)
FAR	-0.073***	-2.441***
	(-6.828)	(-6.137)
Constant	-0.115***	24.259***
	(-3.868)	(16.560)
Observations	2,211	2,202
R-squared	0.249	0.383
Year FE	YES	YES
Industry FE	YES	YES
Pseudo R-sq	0.242	0.377

The table presents regression of firm performance on the R&D intensity and other control variables. In Test (1), ROA is the short-term firm performance indicator. In Test (2), Tobin's Q is a proxy of long-term firm performance. All variables are explained in Appendices. This table reports coefficient estimates with robust t-statistics in parentheses. ***, **, and * are used to indicate the 1%, 5%, and 10% level of significance.

Then, the lag effect of R&D intensity is tested in one, two, and three-year lag period in Model (1), (2) and (3). ROA and Tobin's Q are proxies of firm performance in line with the above analysis. The results are shown in Tables 4 and 5 respectively. For ROA (Table 4), the lagged RDI of the first two lag periods are negatively related to ROA, the coefficient on the one-year and two-year lagged RDI is -0.073 and -0.053, statistically significant at 1% level. In the three-year lag period, RDI is negative to ROA but has a lower significance level at 5% (CO=-0.035, $p<0.05$). Although the coefficient of one year-lag RDI (CO=-0.073) is lower than that of the current-year RDI (CO=-0.061), the overall tendency presents that, the longer the lag period is, the smaller the decrease in ROA with one unit increase of RDI. Specifically, the lag effect of R&D expenditure will mitigate the negative effect on short-term profitability.

To better prove the impact of R&D lag effect on firm performance and identify the tendency across time, this study applies a sensitivity test to uses Tobin's Q as another firm performance proxy. For Tobin's Q (Table 5), the lagged RDI is insignificant to Tobin's Q in all three lag periods ($p>0.1$), consistent with the current-year RDI test. The coefficients of RDI are 0.878, 0.880, and 1.179 respectively in the three lag periods. This progressive increase in coefficient indicates that although the significance is weak, with the extension of the lag period, the positive effect of RDI on Tobin's Q is possible to be stronger. The R&D expenditures incurred in previous years will further contribute to long-term firm performance.

Table 4 Regression analysis of R&D lag effect on return on asset (ROA)

		ROA	
VARIABLES	(1)	(2)	(3)
RDI_{t-1}	-0.073***		
	(-3.953)		
RDI_{t-2}		-0.053***	
		(-3.336)	
RDI_{t-3}			-0.035**
			(-2.270)
SIZE	0.012***	0.014***	0.015***
	(8.489)	(8.804)	(8.645)
LEV	-0.128***	-0.134***	-0.145***
	(-15.940)	(-14.718)	(-13.262)
FAR	-0.070***	-0.065***	-0.061***
	(-6.019)	(-4.973)	(-3.917)
Constant	-0.121***	-0.160***	-0.171***
	(-4.051)	(-5.031)	(-4.564)
Observations	1,854	1,441	1,099
R-squared	0.262	0.272	0.283
Year FE	YES	YES	YES
Industry FE	YES	YES	YES
Pseudo R-sq	0.254	0.262	0.271

The table presents regression analysis of ROA (return on asset) on lagged R&D intensity and other control variables. RDI_{t-n} represent lagged RDI, where n=1, 2, 3 in Test (1), (2), (3) orderly. Test (1), (2), (3) test RDI with the one-year, two-year, and three-year lag period respectively. The results are compared to analyze the tendency as the increase of the lag period. This table reports coefficient estimates with robust t-statistics in parentheses. ***, **, and * are used to indicate the 1%, 5%, and 10% significance level.

Table 5 Regression analysis of R&D lag effect on Tobin's Q

		Tobin's Q	
VARIABLES	(1)	(2)	(3)
RDI_{t-1}	0.878		
	(1.200)		
RDI_{t-2}		0.880	
		(1.371)	
RDI_{t-3}			1.179
			(1.185)
SIZE	-0.773***	-0.754***	-0.758***
	(-15.632)	(-14.485)	(-13.113)
LEV	-1.311***	-1.386***	-1.461***
	(-4.783)	(-4.440)	(-4.082)
FAR	-2.483***	-2.302***	-2.111***
	(-5.662)	(-4.713)	(-4.078)
Constant	0.878	0.880	1.179
	(1.200)	(1.371)	(1.185)
Observations	1,751	1,352	1,030
R-squared	0.377	0.386	0.386
Year FE	YES	YES	YES
Industry FE	YES	YES	YES
Pseudo R-sq	0.369	0.377	0.375

The table presents a sensitivity test for the R&D-firm performance relationship with the R&D lag effect. RDI_{t-n} represent lagged RDI, where n=1, 2, 3 in Test (1), (2), (3) orderly. Test (1), (2), (3) test RDI with the one-year, two-year, and three-year lag period respectively. The results are compared to analyze the tendency as the increase in the lag period. All variables are explained in Appendices. This table reports coefficient estimates with robust t-statistics in parentheses. ***, **, and * are used to indicate the 1%, 5%, and 10% significance level.

Considering two different firm performance indicators, the result supports the hypothesis H3 that the R&D expenditure cannot take an obvious effect immediately in the year of expense, but it has more explicit, favorable effects after lag periods. This study shows that among the three years next to the incurrence of R&D expenditures, R&D has the strongest effect in the three-year lag period, but the significance level of the relationship starts to decrease at the three-year lag period. It can be concluded that the two-year lag period has both significant and relatively strong R&D-firm performance relationship. Overall, the changes in coefficient among years are consistent with Campbell (2012) to support that the R&D expenditure has the time lag effect on firm performance. Also, the results of lag periods are in line with that of Guan and Chen (2010) that the two-year lag period is approximately the most appropriate for Chinese research-intensive industries.

V. CONCLUSION

This paper aims to investigate the links between R&D intensity and the firm performance of Chinese high-and new-technology industries in both the short term and long term. The prediction is that R&D intensity worsens the current firm performance but promotes the long-term performance, because the efficiency of R&D expenditure can be improved as the changes of corporate environment, structure, and resources (Sorensen and Stuart 2000; Garud and Nayyar 1994). Further, this paper hypothesizes that R&D expenditures have the lag effect to delay the current favorable performance and take effects after the lag periods.

To test these hypotheses, this paper empirically analyzes the relationship between R&D intensity involving lag effects and the proxies of the firm performance. The results present that R&D intensity is negative to the current profitability measured by return on assets (ROA), and it insignificantly contributes to long-term performance measured by Tobin's Q. For the R&D lag effect, with the extension of the lag periods, the negative effect on profitability is progressively mitigated, and the long-term performance is further promoted.

The empirical results generally support previous assumptions that the R&D intensity has different effects on firm performance in short term and long term (Ayadi et al. 1996; Guo et al. 2004; Vithessonthi and Racela 2016; Xu and Jin 2016). Although the difference in periods is in line with previous studies, this study indicates that Tobin's Q may not be an effective long-term performance indicator in Chinese high-and new-technology industries, or other factors should interact with R&D to significantly improve firm performance. Also, this study adds lag periods from one to three-year to R&D to test the R&D lag effect in detail. The results indicate an explicit time interval between the incurrence and effectiveness of R&D. This evidence benefits the time management of R&D expenditures and firm performance evaluation in practice.

For the suggestions to further studies of the relationship between R&D and firm performance, firstly, this study does not involve moderating or interactive effects to R&D. As the empirical results suggest, other than R&D intensity, both basic firm indicators such as firm size, financial leverage, and fixed assets ratio are associated with firm performance. Additionally, prior studies point out other complicated factors that relate to R&D and contribute to the firm development, for example, internationalization degree (Vithessonthi and Racela 2016) and commercialization orientation (Lin et al. 2006). Thus, the interaction or trade-off among those elements should be involved to refine the model and to test the R&D effectiveness comprehensively. Secondly, since Tobin's Q alone is ineffective to indicate the long-term firm performance in this study, future research should find an appropriate way to measure the market value of Chinese firms or integrate another effective indicator with R&D to estimate the long-term firm performance. Finally, although this study narrows to high-and new-technology industries, the threshold of R&D intensity level is not added into variables to test the existence of a turning point in the effectiveness of R&D expenditures. Threshold value refers to the optimal level of R&D to maximize firm performance (Yeh et al. 2010). This element is worth to consider because it deeply explores the effectiveness of current expenses and enlightens companies to calculate their threshold value by own at the incurrence stage of R&D expenditures (Yeh et al. 2010; Vithessonthi and Racela 2016).

Appendices

Table A1 Variables Description

Variables	Description
PERF	PERF is the proxy measure of firm performance. It is replaced by ROA in the short-term performance test and Q in the long-term performance test.
ROA	Return on assets is computed as the ratio of net income to average total assets to indicate short-term firm performance.
Tobin's Q	Tobin's Q, as a long-term firm performance indicator, is defined as the ratio of firm market value to its book value. Chung and Pruitt (1994) develop a model to approximate Q as (outstanding stock value + preferred stock value + total liability)/ total assets, where the numerator is a proxy of market value, and the total assets represent the firm book value. In this study, the data of market value are derived from CSMAR, calculated by (total shares - share) × closing price of A share + B share × closing price of B share + total liabilities).
RDI	Research & Development Intensity is applied to indicate a firm's strategic use of R&D and a firm's innovation ability. It equals R&D expenditures / total sales. The data of R&D expenditures are obtained from the balance sheet in financial statement. In this study, RDI_{t-n} is a lagged variable and refers to the R&D intensity from n years ago, where *n=0* represents RDI in the testing year, *n=1,2,3* represents RDI from previous *n* years to test whether previous R&D will have effects on current performance.
SIZE	Firm size has been considered a factor affecting firm performance in previous literature reviews (Lin and Chen 2005). It equals the natural logarithm of the total assets.
LEV	Leverage ratio is computed as the total liabilities to total assets. It is used by firms as a means to increase profits (Yeh et al, 2010).
FAR	Fixed assets ratio is computed as the value of total fixed assets to total assets, affecting the influence of fixed assets over total assets and profit generation.
YEAR	This dummy variable is applied to control the year fixed effect and exclude the influence of past investment. It covers a ten-year period from 2007 to 2016.
IND	This dummy variable is applied to control the industry fixed effect. This study includes nine high-and new-technology industries according to China Statistics Yearbook on High Technology Industry and China Securities Regulatory Commission (CSRC) industry classification. Categories with codes in parentheses are shown as follow. Pharmaceutical manufacturing (C27), special equipment manufacturing (C35), railway, shipbuilding, aerospace and other transportation equipment manufacturing(C37), electric machines and apparatuses manufacturing (C38), computer, communication and other electronical device manufacturing (C39), telecommunications, broadcast, television, and satellite transmission services (I63), internet and related services (I64), software and IT services(I65), ecological preservation and environmental treatment industry (N77).

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