Impact of Research and Development Investment on the Performance
Evidence from Artificial Intelligence Companies

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Abstract
Artificial intelligence (AI) has gradually become an important factor in enhancing the core competitiveness of a country. This paper is based on the data of 40 AI companies from 2018 to 2020 as samples, and conducts an empirical research on the impact of research and development (R&D) investment on corporate performance. The results show that R&D investment cannot significantly influence the performance of AI companies in the short term, but have a positive effect in the long run, especially in the second lag period. AI companies should take measures to improve their R&D activities and relevant works, thus promoting the AI development in China.

Keywords: *AI companies; R&D investment; innovation; corporate performance*

1 INTRODUCTION

In 2021, according to China's 14th Five-Year Plan, a new generation of information technology represented by AI will become an important factor in promoting high-quality economic development, building an innovative country and realizing industrialization, informatization, urbanization and agricultural modernization to a higher level. AI companies, of which the core business is to provide and apply artificial intelligence products and services, such as iFLYTEK (002230), GRGBanking (002152) and PCITECH (600728), have become a driving force for AI development in China to achieve technological breakthroughs and optimize application levels.

The International Monetary Fund suggests that it is necessary to increase R&D investment in order to ensure better economic growth in the future. Although the impact of R&D investment on companies is risky and may have negative influence, companies definitely cannot ignore its positive side. AI companies must enhance their R&D investment and promote technological innovation to create new economic growth as well as economic development models. Therefore, it is critical to improve corporate performance and enhance the overall competitiveness of the AI industry, thus contributing to China's economic growth as well as scientific capability. To sum up, this paper aims to explore the impact of R&D investment on the performance of AI companies, and provide further suggestions to inspire AI companies for their future development.

2 REVIEW OF RELATED RESEARCH

Of the many who have looked at the relationship between R&D investment and corporate performance has yet produced a definite answer. Lu Keying (2017) for instance, found that R&D investment had a significant positive impact on corporate performance and the results showed time-lag effect [1]. Yue Yujun and Meng Miao (2022) insisted that the impact of R&D investment in lag period outweighed that in current period [2]. Ping-Hung Hsieh, Chandra S. Mishra and Dave H. Gobeli (2003) found positive associations of R&D intensity and firm performance [3]. Meng Qingjun and Gu Jiale (2020) believed that R&D investment was significantly positively correlated with a company's core competitiveness [4]. Abhishek Kumar Sinha, Aswini KUMAR Mishra and Yash Patel (2019) found that R&D expenditure had statistically significant effects on firms' total income [5]. Yu Yan (2014) suggested that the R&D

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investment was negatively correlated with performance [6]. Wang Ye and You Chun (2009) believed that R&D intensity had nothing to do with performance indicators such as ROE and EPS, which was also not affected by time-lag effect [7].

Current research on the relationship between the R&D investment and the performance of AI companies is relatively limited. Kong Xu, Hao Feiyan, Liu Peipei and Zhang Lianbiao (2021) believed that exploratory innovation had significant positive effect on AI companies' performance, while exploitative innovation had an opposite effect [8]. Wang Xueyi and He Taiyi (2021) insisted that R&D investment could promote the improvement of corporate performance through interaction effect with human capital [9]. Therefore, this paper has selected 40 AI companies as research object to explore the impact of R&D investment on the current performance and the lag performance respectively based on input-output theory.

3 RESEARCH METHODS AND DESIGN

3.1 *Hypotheses*

On the basis of current research, the majority holds the view that R&D investment has a significant impact on performance in both current and lag period, so this paper performs a test of Hypothesis 1 and Hypothesis 2:

H1: R&D investment has a significant impact on the performance in the current period.

H2: R&D investment has a significant impact on the performance in the lag period.

The performance of a company is usually reflected in four aspects: profitability, operating capability, solvency and development ability. Based on above four aspects, further hypotheses are suggested.

3.1.1 The impact of R&D investment on profitability

R&D investment benefits products and services, boosting efficiency and profitability. However, because of time-lag effect, which prevents increasing profitability due to the capital occupation, the positive impact of R&D investment will gradually become significant during lag period. So it is going to perform a test of Hypothesis 3:

H3: R&D investment is negatively correlated with the profitability in current period but positively in lag period.

3.1.2 The impact of R&D investment on operating capability

In the short term, the increase in R&D investment will slow down the asset turnover of capital and reduce utilization efficiency, but in the long run, it plays an important role in optimizing the cost structure and enhancing the corporate management quality, which benefits operating capability. Then Hypothesis 4 is suggested:

H4: R&D investment is negatively correlated with the operating capability in current period but positively in lag period.

3.1.3 The impact of R&D investment on solvency

In current period, R&D investment restrains debt-paying ability owing to the occupation of cash flow. However, with increasing profit, it is conducive to reducing debt and improving solvency. Then Hypothesis 5 is suggested:

H5: R&D investment is negatively correlated with the solvency in current period but positively in lag period.

3.1.4 The impact of R&D investment on development ability

The R&D investment may not have an obvious effect on current operation conditions, and may even lead to a decline in development ability due to the insufficient market demand for new products. Yet in the long term, investing in R&D benefits market development and development ability. Then Hypothesis 6 is suggested:

H6: R&D investment is negatively correlated with the development ability in current period but positively in lag period.

3.2 *Data sources*

This paper selects listed AI companies disclosed by the Shanghai Stock Exchange and the Shenzhen Stock Exchange from 2018 to 2020 as the object, excluding companies which are ST and ST* or have abnormal or missing data. 40 representative AI companies including iFLYTEK (002230), GRGBanking (002152) and PCITECH (600728) are used as samples for further analysis. Data mainly comes from CSMAR database.

The variables are set as follows (Table I):

1) Explained variables: Select return on total assets (Roa), total asset turnover (Tat), asset-liability ratio (Lev) and revenue growth rate (Gro) as indicators of profitability, operating capability, solvency and development ability respectively, which jointly reflect the corporate performance.

2) Explanatory variable: Use R&D intensity as the explanatory variable, which reflects the degree of R&D investment.

3) Control variables: Select enterprise size, enterprise age and capital as the control variables, since they could affect the corporate performance.

TABLE I. TERMS AND DEFINITIONS OF VARIABLES

Variable		Term	Symbol	Formula
Expl-ained vari-ables	*Profitability*	Return on total assets	Roa	Net profit/ Total asset
	Operating capability	Total asset turnover	Tat	Revenue/ Total asset
	Solvency	Asset-liability ratio	Lev	Total liability/ Total asset
	Development ability	Revenue growth rate	Gro	Increase of revenue/ Revenue of last year
Explanatory variable		R&D intensity	R&D	R&D investment/ Revenue
Control variables		Enterprise size	Size	Ln (Total asset)
		Enterprise age	Age	Current date -Establishment date
		Capital	Cash	Monetary capital/ Total asset

3.3 *Models*

According to hypotheses and variables above, models are constructed as follows:

1) The regression model of R&D in*vestment and current performance:*

$$Y_t = a_0 + \alpha_1 R\&D_t + \alpha_2 Size_t + \alpha_3 Age_t + \alpha_4 Cash_t + \epsilon_t \quad (1)$$

2) The regression model of R&D investment and lag performance:

In the first lag period:

$$Y_t = b_0 + \beta_1 R\&D_t + \beta_2 R\&D_{t-1} + \beta_3 Size_t + \beta_4 Age_t + \beta_5 Cash_t + \epsilon_t \quad (2)$$

In the second lag period:

$$Y_t = c_0 + \gamma_1 R\&D_t + \gamma_2 R\&D_{t-1} + \gamma_3 R\&D_{t-2} + \gamma_4 Size_t + \gamma_5 Age_t + \gamma_6 Cash_t + \epsilon_t \quad (3)$$

t represents time, Y_t represents the performance, $R\&D_t$, $R\&D_{t-1}$and $R\&D_{t-2}$ represent the R&D intensity of the current period, the first lag period and the second lag period respectively, $Size_t$, Age_t and $Cash_t$ are the control variables, a_0, b_0 and c_0 are the intercept terms, α_i, β_i and γ_i are the regression coefficients, and ϵ_t is the error term.

3.4 *Research methods*

Establish multiple linear regression models and use Stata15 for the empirical analysis. The study aims to find the impact of R&D investment on the performance of AI companies. The following procedures are:

1) Determining model: Choose between fixed effect model, random effect model and mixed regression model through LM test and Hausman test.

2) Test for multicollinearity: Test variables for multicollinearity through Pearson correlation coefficient and variance inflation factor (VIF).

3) Regression analysis: Conduct a regression analysis on the linear relationship between R&D investment and performance of AI companies and its significance through t-test and F-test.

4 RESULTS & DISCUSSION

4.1 *Descriptive Statistics*

4.1.1 R&D investment

Table II shows the results of descriptive statistics on R&D intensity. From the mean values, the average R&D intensity in three years are 12.70%, 13.55% and 13.26% respectively, which are all far higher than 5%, thus indicating a high R&D intensity. It shows that AI companies attach great importance to R&D investment and have sufficient competitiveness. From the maximum and the minimum values, some companies' R&D intensity can reach 44%, while some companies' R&D intensity is less than 1%. It can be seen that R&D investments of different AI companies are unbalanced. Although AI companies are knowledge-intensive and technology-intensive, there are still several companies with low R&D investment and unbalanced development. The trend of standard deviation from 2018 to 2020 was increased from 2018 to 2019 before it went down in 2020, indicating a large gap in R&D investment among AI companies in 2019. Overall, the fluctuation is not huge as it is at a relatively stable level.

TABLE II. DESCRIPTIVE STATISTICS OF R&D INTENSITY

Year	N	Min	Max	Mean	SD
2018	40	0.0006	0.3605	0.1270	0.0842
2019	40	0.0008	0.4407	0.1355	0.0919
2020	40	0.0009	0.3890	0.1326	0.0868

4.1.2 Main variables

Table III shows the results of descriptive statistics on main variables. In terms of return on total assets, the mean value is 1.4%, the maximum value is 24.1%, the minimum value is only -47.3%, and the standard deviation is 10.0%. In terms of total asset turnover, the mean value is 43.5%, the maximum value is 95.0%, the minimum value is 12.4 %, and the standard deviation is 19.9%. In terms of asset-liability ratio, the mean value is 33.7%, the maximum value is 67.1%, the minimum value is 7.7%, and the standard deviation is 15.3%. In terms of revenue growth rate, the mean value is 35.4%, the maximum value is as high as 215.7%, the minimum is as low as -97.5%, and the standard deviation is 48.3%. It shows that there are gaps in profitability, operating capability, solvency and development ability among AI companies, and the performance is not stable enough.

The average R&D intensity of AI companies has a ideal value of 13.2%. The standard deviation of the three control variables is a little high, which can have a certain impact on the performance.

TABLE III. DESCRIPTIVE STATISTICS OF MAIN VARIABLES

VARIABLES	N	min	max	mean	sd
Roa	120	-0.473	0.241	0.0140	0.100
Tat	120	0.124	0.950	0.435	0.199
Lev	120	0.077	0.671	0.337	0.153
Gro	120	-0.975	2.157	0.354	0.483
R&D	120	0.001	0.441	0.132	0.087
Size	120	20.620	25.520	22.320	0.927
Age	120	9.08	31.75	18.44	5.904
Cash	120	0.0368	0.856	0.209	0.155

4.2 *Multicollinearity Testing*

Multicollinearity test (Table IV) shows that the correlation coefficients between variables are all no greater than 0.8, indicating that there is no strict multicollinearity between the explanatory variables. By using VIF test, results show that VIF are all far less than 10, further indicating that there is no multicollinearity.

TABLE IV. MULTICOLLINEARITY TESTING

	Roa	Tat	Lev	Gro	R&D	Size	Cash	Age
Roa	1							
Tat	0.099	1						
Lev	-0.202**	0.440***	1					
Gro	0.274***	0.072	-0.111	1				
R&D	0.037	-0.330***	-0.604***	0.058	1			
Size	0.148	0.301***	0.342***	0.027	-0.308***	1		
Cash	0.297***	-0.128	-0.406***	0.058	0.241***	-0.104	1	
Age	-0.042	0.12	0.333***	-0.024	-0.443***	0.385***	-0.123	1
VIF	1.27	1.33	2.07	1.03	1.78	1.3	1.2	1.38

*** p<0.01, ** p<0.05, * p<0.1

4.3 *Regression Analysis*

Through model (1), it performs a linear regression analysis on the data (Table V) using Stata15. The results show that in current period, R&D investment is significantly related to return on total assets and total asset turnover at 10% level, while asset-liability ratio and revenue growth rate are not significantly affected by R&D investment. Hypothesis 1 is not true.

TABLE V. REGRESSION RESULTS IN THE CURRENT PERIOD

VARIABLES	Roa	Tat	Lev	Gro
R&D	-0.691*	-0.702*	-0.034	-0.699
	(-1.94)	(-1.96)	(-0.20)	(-0.52)
Size	0.191*	-0.102**	-0.03	0.336*
	-1.94	(-2.28)	(-0.36)	-1.73
Cash	0.025	0.007	-0.039	0.874
	-0.2	-0.05	(-0.20)	-1.32
Age	-0.031**	0.002	0.021***	-0.007
	(-2.54)	-0.27	-3.15	(-0.17)
Constant	-3.594*	2.763***	0.634	-7.105*
	(-1.72)	-2.96	-0.34	(-1.79)
R-squared	0.266	0.184	0.123	0.057
F test	0.00142	0.112	0.0223	0.0664
r2_a	0.24	0.156	0.0921	0.0239
F	5.433	2.01	3.222	2.4

*** p<0.01, ** p<0.05, * p<0.1

Model (2) and Model (3) perform linear regression analysis on the data (Table VI, Table VII) using Stata15. The results show that in the first lag period, there is no significant correlation between R&D investment and explained variables. However, in the second lag period, the relationship between R&D investment and total asset

turnover and the relationship between R&D investment and revenue growth rate are both significant at the level of 1%. R&D investment also shows significant correlations with return on total assets and asset-liability ratio at the level of 10%. Comparing the results in the first lag period and those in the second lag period, it is obvious that the results in the second lag period are more significant. Hypothesis 2 is true.

TABLE VI. REGRESSION RESULTS IN THE FIRST LAG PERIOD

VARIABLES	Roa	Tat	Lev	Gro
$R\&D_{t-1}$	0.1	0.047	-0.081	0.414
	-0.46	-0.44	(-0.66)	-0.41
Size	0.194*	-0.101**	-0.033	0.349*
	-1.93	(-2.16)	(-0.38)	-1.91
Cash	0.031	0.009	-0.043	0.896
	-0.24	-0.07	(-0.22)	-1.32
Age	-0.032**	0.002	0.022***	-0.011
	(-2.56)	-0.21	-3.21	(-0.28)
Constant	-3.661*	2.732***	0.687	-7.378*
	(-1.72)	-2.83	-0.36	(-1.98)
R-squared	0.267	0.185	0.125	0.058
F test	0.000741	0.129	0.0274	0.0942
r2_a	0.235	0.149	0.0863	0.0169
F	5.382	1.831	2.852	2.04

*** p<0.01, ** p<0.05, * p<0.1

TABLE VII. REGRESSION RESULTS IN THE SECOND LAG PERIOD

VARIABLES	Roa	Tat	Lev	Gro
$R\&D_{t-2}$	0.434*	0.992***	0.316*	3.857***
	-1.77	-4.7	-1.71	-3.3
Size	0.193*	-0.104**	-0.034	0.337*
	-1.95	(-2.53)	(-0.40)	-1.96
Cash	0.035	0.019	-0.04	0.933
	-0.27	-0.14	(-0.21)	-1.47

Age	-0.036***	-0.008	0.019**	-0.048
	(-2.72)	(-0.89)	-2.55	(-1.18)
Constant	-3.619*	2.827***	0.717	-7.008*
	(-1.73)	-3.32	-0.38	(-1.99)
R-squared	0.281	0.37	0.145	0.141
F test	0.000586	0.000143	0.000931	0.00883
r2_a	0.243	0.336	0.0991	0.0952
F	5.115	6.095	4.807	3.381

*** p<0.01, ** p<0.05, * p<0.1

Through regression analysis, following regression results are obtained:

4.3.1 The impact of R&D investment on profitability

R&D investment is significantly negatively correlated with return on total assets by 10% (Table V), while is positively but not significantly correlated with return on total assets in the first lag period (Table VI), and is significantly correlated with return on total assets in the second lag period by 10% (Table VII). The adjusted R^2 is 0.243, which shows that the fit indicators of this model are acceptable and hypothesis 3 is true.

R&D investment influences the overall investment of a company, which reduces the profitability in the current period. However, with time-lag effect, technological innovation brought by R&D investment is conducive to developing company business and profitability.

4.3.2 The impact of R&D investment on operating capability

R&D investment has a negative effect on total asset turnover currently, which is significant at 10% level (Table V). But it has a positive effect in the lag period, and is significant at the level of 1% in the second lag period (Table VI, Table VII). The adjusted R^2 is 0.336, which shows that fit indicators of this model are acceptable and hypothesis 4 is true.

Increasing R&D investment reduces the turnover of capital, which consequently results in a series of problems such as capital occupation and poor operating capability. R&D investment leads to the optimization of the cost and the efficiency, thus operating capability will be improved in lag period.

4.3.3 The impact of R&D investment on solvency

R&D investment has a negative but insignificant correlation with asset-liability ratio in the current period and in the first lag period (Table V, Table VI). However, it has a significant positive correlation at the level of 10% in the second lag period (Table VII). Therefore, hypothesis 5 is true.

R&D investment affects company cash flow, but is difficult to significantly influence its solvency in the short term. Only after a long period of time could R&D investment have a huge impact on solvency.

4.3.4 The impact of R&D investment on development ability

R&D investment is negatively correlated with the current revenue growth rate (Table V), but is positively correlated with the lagging revenue growth rate (Table VI, Table VII). The significance level is at 1% in the second lag period which shows hypothesis 6 is true.

R&D investment is cyclical and can hardly have a significant impact on company's development ability immediately. Nevertheless, in the long run, it is going to increase company revenue, enhance profits and boost development ability.

5 CONCLUSION

This paper is based on the panel data of 40 AI companies from 2018 to 2020 by conducting an empirical analysis with multiple linear regression models, on the impact of R&D investment on corporate performance. Consequently, we are able to draw a conclusion that AI companies' R&D investment has a positive effect on their performance. However, the effect cannot be seen

currently as it needs to pass through lag period, and become more significant in the second stage of lag period.

This research finds how R&D investment impacts the performance of AI companies, and puts forward further suggestions for their future development. It is hoped that this paper will make a modest contribution to AI development in China, achieving technological breakthroughs and optimizing application levels.

Based on the conclusion, following suggestions are made:

5.1 *Increasing R&D investment*

AI companies are supposed to maintain a high level of R&D investment. According to the European Union (EU) statistical standard, R&D investment which accounts for more than 5% of a company's operating revenue is considered as high R&D intensity. Therefore, AI companies in China whose R&D intensity are less than 5% should increase their R&D investment as soon as possible to improve their technological level and innovative ability, thus achieving a better corporate performance.

5.2 *Reasonably coordinating R&D activities*

The positive impact of R&D investment on the performance has a lag period which can last for more than 2 years. As a result, AI companies need to arrange R&D activities reasonably, optimize the resource allocation and shorten the R&D investment cycle to accelerate the productization and commercialization process of R&D investment. Moreover, enhancing financial management and providing R&D earmarked funds, to some extent, are able to solve capital occupation and imbalanced investment structure problems, which consequently accelerates corporate performance. Meanwhile, group incentive mechanism should be adopted to encourage R&D activities.

5.3 *Efficient disclosure of R&D information*

Since R&D investment influences a company's stock price, lack of efficient disclosure will damage company reputation at the cost of losing investors' trusts. AI companies should increase the level of R&D information disclosure by disclosing the progress of R&D projects, current achievements and potential risks. Investors, therefore, can better understand the R&D activities which is beneficial to company's R&D investment.

5.4 *Improving government subsidy mechanism*

Government should establish a stable R&D investment growth mechanism to accelerate the transformation of scientific and technological achievements. Policies related to R&D subsidy and funding can be improved, such as increasing the maximum annual subsidy for a company from 500,000RMB to 800,000RMB, which may boost AI companies' R&D investment.

5.5 *Sharing innovative resources*

AI companies should cooperate with scientific research institutes and universities by recruiting qualified scientists and high-tech talents. In addition, banks should provide AI companies with low-interest loans, thus enhancing the stability of their future R&D budgets and plans.

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