

The Moderating Effect of Value Cognition and Market Competition: A Study of the Relationship between R&D Intensity and Performance of AI Enterprise

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Abstract: From the perspective of value cognition and innovation theory, using panel data of 75 listed companies in China's AI concept stocks from 2011 to 2019 as samples, this paper analyzes and examines the influence of R&D intensity of AI enterprises on enterprise performance and the regulatory effect of value cognition and market competition in this process. Studies have shown that the R&D intensity of AI enterprises is positively correlated with their performance. In addition, the complexity of value cognition and the pressure of market competition have a negative regulatory effect on the relationship between the R&D intensity and performance of AI enterprises.

1 INTRODUCTION

In the field of AI, technology is updated rapidly and R&D investment is high. Except for a few leading enterprises with sufficient funds, it is difficult for business managers and science and technology decision-makers to balance the survival and development of start-ups between market efficiency and R&D investment (Xu 2021). AI enterprises are high-tech companies; R&D and innovation are the keys to maintaining their market competitiveness. However, this issue is rarely mentioned in existing studies.

First, there are controversies surrounding the relationship between R&D intensity and enterprise performance. In some researches, it is believed that the R&D investment intensity of an enterprise is positively correlated with enterprise performance (Mudambi 2014). In other researches, it is believed that the two are negatively correlated or have a nonlinear relationship (Racela 2016, KANG 2013). However, in the existing researches, there are few discussions about the relationship between the R&D intensity and performance of AI enterprises.

Furthermore, value cognition and market competition affect the relationship between R&D intensity and performance of AI enterprises. This is because the R&D and innovation process of

enterprises belongs to the value creation process, and the decision-making of R&D is affected by the cognitive level of business managers. It is generally believed that the more complex the manager's value cognition, the more exploration opportunities the enterprise has, the higher the enterprise's exploration capabilities (Daniella 2018, Stabell 1978), and the greater the possibility that the enterprise will increase R&D investment. However, when the value cognition is very complex, enterprises should place resources in multiple links of the innovation value chain, resulting in resource fragmentation and resource waste. Enterprise performance cannot be improved in a short time. Finally, in most existing studies, it is believed that under the high pressure of market competition, leading enterprises will maintain their competitive advantage by increasing R&D investment. However, for AI enterprises in the early stages of development, there is currently no research on whether R&D and innovation can ensure the growth of enterprise performance.

In order to make up the research gap, from the perspective of value cognition and innovation theory, with 75 listed companies in AI concept stocks from 2011 to 2019 as the objects of study, this paper studies the relationship between the R&D intensity and performance of AI enterprises and the moderating effect of the complexity of value

cognition and market competition on this relationship to reveal the boundary conditions of the influence of the R&D intensity of AI enterprises on enterprise performance.

2 THEORETICAL BASIS AND HYPOTHESES

2.1 R&D Intensity and Performance of AI Enterprises

According to the innovation theory of Joseph Alois Schumpete, science and technology are the driving force for the development of enterprises, and the core competitiveness of enterprises is formed through R&D activities. The investment in innovation of an enterprise is mainly reflected in the intensity of R&D investment (SUN 2019). In the field of AI, technology is updated rapidly and R&D investment is high. Through R&D and innovation, AI enterprises can obtain heterogeneous resources, promote the launch of high-quality products, help enterprises to seize a larger market share, and develop lasting competitive advantages. In addition, according to some scholars, by increasing innovation investment, high-tech enterprises can improve their future business performance (Pand 2011, Ciftci 2011). As AI enterprises are high-tech enterprises, their R&D expenditures are in line with the needs of the enterprise's long-term development strategies. The successful transformation of R&D achievements will ultimately lead to the economic growth of enterprises. On this basis, Hypothesis 1 was proposed.

H1: The R&D intensity of AI enterprises has a positive influence on enterprise performance.

2.2 The Influence of Value Cognition on the Relationship between R&D Intensity and Performance of AI Enterprises

The complexity of value cognition refers to the breadth of the knowledge covered by the managers' knowledge structure (Walsh 1995, Nadkarni 2008). From the perspective of value creation, it is the number of links in the value chain that managers paid attention to. If the complexity of value cognition is high, it means that managers recognize various core concepts (SHANG 2014) and ideas about the technology field comprehensively in the process of R&D investment, thereby increasing the possibility of enterprises obtaining long-term value through

R&D investment. However, the ideas are so comprehensive that they will use up more resources. The more complex the value cognition in the R&D investment process of AI enterprises, the more value chains they pay attention to. This will lead to the reallocation of resources distributed in multiple value chains, which does not help with the concentration of enterprise resources and may cause higher sunk costs (CHEN 2021). Enterprise performance cannot be improved. Therefore, the negative influence of the increased R&D investment on performance in the short term will not be reduced due to the higher complexity of value cognition. On this basis, Hypothesis 2 was proposed.

H2: The complexity of value cognition has a negative moderating effect on the relationship between R&D intensity and performance of AI enterprises.

2.3 The Influence of the Pressure of Market Competition on the Relationship between R&D Intensity and Performance of AI Enterprises

The R&D intensity and performance of AI enterprises are affected by both internal and external factors. The R&D strategies of the enterprises are affected by the intensity of market competition (JIAN 2017), and the competition in China's AI industry is intense. Once the competitor has launched new products or offered the same products at lower prices, management is forced to make targeted R&D decisions (ZHENG 2018). With the increasingly intense market competition, AI enterprises continue to increase R&D investment in order to maintain their competitive advantages. However, in the early stage of enterprise R&D activities, the operating pressure of funds was relatively high, and it was difficult to obtain returns in a short time. At the same time, the risks of R&D increase, and the possibility that the innovative achievements of an enterprise are imitated or being surpassed by follow-suitors increased (JIANG 2021). On top of that, the AI industry in China is still at an early stage of development. If enterprises in the growth stage invest too much, their future performance will be poor (Fedyk 2017). On this basis, Hypothesis 3 was proposed.

H3: The pressure of the market competition pressure has a negative moderating effect on the relationship between R&D intensity and performance of AI enterprises.

3 METHODS

3.1 Samples and Data Sources

Sample selection: The research samples of this paper were selected from Tonghuashun AI concept stocks listed companies from 2011 to 2019. At the same time, considering the lag effect of R&D intensity of enterprises on enterprise performance, in this paper, 1 year was considered as the lag phase. The data from 2011 to 2018 were used as independent variables, regulated variables, and control variables, whereas the data from 2012 to 2019 were used as the dependent variables. After excluding ST and *ST companies, there were 75 listed companies in the final samples. STATA15 software is used to process the above-mentioned data.

Data source: Annual reports and social responsibility reports of listed companies originated from cninfo.com.cn, combined with the enterprises' official websites for supplementary verification. Most of the data on R&D intensity, enterprise performance, and control variables are sourced from CSMAR, where some R&D intensity research data have been supplemented through the enterprises' annual reports. By identifying and manually collecting key sentences in the enterprise's annual report and social responsibility report, the complexity of value cognition was obtained.

3.2 Variable Definition and Metric

1) Dependent variable: enterprise performance (TBQ).

Based on the reference (HE 2021), in this paper, we decided to measure the enterprise performance with the profit index. In other words, we measure the enterprise performance with the ratio of market value to total assets.

2) Independent variable: R&D intensity (RD).

R&D intensity refers to the intensity of enterprises investing limited resources in R&D. For the measurement of R&D intensity, refer to the practices of Barker & Mueller (Barker, Mueller 2002) and Lv Diwei et al. (Diwei 2018). This paper measures the R&D intensity of an enterprise with the ratio of its R&D expenditure to total sales in year. The greater the value of this variable, the higher the R&D investment intensity of the enterprise.

3) Moderator variable: complexity of value cognition (NC).

The coding research design of Nadkarni and Narayanan (Nadkarni, Narayanan 2007) and Wu Dong (Wu 2011) were used for reference and

integration. In this research, the text analysis method was used to describe the complexity of cognition of AI enterprises in the process of R&D and innovation. There are mainly the following two steps.

Step 1: The statements were identified. The annual reports and social responsibility reports of the companies were studied, and according to the coding vocabulary in the link of value creation summarized by Wu Dong (Wu 2011) in his research, the sentences showing that the enterprises have considered the factors in each link of value creation in the innovation strategy planning in each annual report were scientifically identified and recorded.

Step 2: In the selected sentences, the number of links (such as R&D, production, market, manpower, and operation) in the chain of value creation considered was determined and recorded as the value of complexity of value cognition. The greater the value of complexity, the more links of value creation are considered in the cognition process of decision-making of the enterprise.

4) Moderator variable: Market competition pressure (HHI).

By using previous researches as a reference, this paper measures the pressure of market competition of the industry in which the enterprise is based with the Herfindahl-Hirschman Index (HHI). The HHI is a comprehensive index used to measure industrial concentration. The smaller the index, the lower the market concentration of the industry, and the more intense the competition. It can be calculated as follows.

$$HHI = \sum_{i=1}^n \left(\frac{x_i}{x}\right)^2$$

In which, x_i represents the operating revenue of the i enterprise, " x " represents the sum of the operating revenues of all the enterprises in the industry, $\frac{x_i}{x}$ represents the market share of the " i " enterprise, and " n " represents the total number of enterprises in the industry.

5) Control variable

This paper selects the size of the enterprise (Size), whether the chairman serves as the general manager (CEO), industry (IND), asset-liability ratio (LEV), the nature of enterprise ownership (SOE), and slack resources (SLK) as control variables.

4 RESULTS

4.1 Narrative Statistics and Analysis

The descriptive statistics and correlation analysis of the variables are shown in Table 1. The average performance of AI enterprises is 2.593, which indicates an average performance from the AI enterprises in China, whereas the average R&D intensity is 0.110. In other words, the R&D investment accounts for more than 10% of operating

revenue. This shows that AI enterprises in China attach importance to R&D investment. The average complexity of value cognition is 4.410, which indicates that many links of value creation are evaluated by AI enterprises in China in the process of R&D and innovation, and there are big differences. The average value of HHI is 0.187, which indicates that the pressure of the market competition of enterprises in different industries is relatively high. It can be seen from the table that R&D intensity is significantly positively correlated with enterprise performance, preliminarily supporting H1.

Table 1 Pearson correlation analysis and Descriptive statistics of all variables

Variables	1	2	3	4	5	6	7	8	9	10	11
TBQ	1										
RD	0.206** *	1									
NC	-	-0.0290	1								
HHI	0.0390	-	-0.075*	1							
Size	-	-	0.361** *	0.0330	1						
LEV	-	-	0.395** *	-0.0410	0.609** *	1					
SOE	-0.0170	-0.0520	0.149** *	0.115** *	0.293** *	0.083**	1				
CEO	-0.0360	-0.0110	0.0470	0.00100	0.311** *	0.229** *	0.120** *	1			
SLK	-0.0110	0.281** *	-0.00600	-0.0340	-	-	-0.0420	-	1		
IND	0.245** *	0.224** *	-	-0.072*	-	-	-	0.077**	-0.0530	1	
Year	0.0180	0.00200	0.078**	0.0250	0.382** *	0.205** *	-0.00800	0.146** *	-	0.164** *	0.035
Mean	2.593	0.113	4.410	0.187	22.09	0.310	0.269	1.615	5.063	2.942	2.015
S.D	1.766	0.125	1.823	0.212	1.275	0.175	0.444	0.487	11.02	1.963	2.584

Note: *p<0.1, **p<0.05, ***p<0.01

4.2 Hypothesis Testing

In order to verify the hypothesis proposed above, this paper analyzed data with stata15.0. Since the original hypothesis was rejected by the Hausman test, a fixed-effect model was used.

1) Test on the main effect of R&D intensity of AI enterprises and the enterprise performance

As shown in Table 2, Model (1) is a regression model that only contains control variables, and in

Model (2) R&D intensity of the enterprise, an independent variable is added. It can be seen from Model (2) that the R&D intensity of an enterprise is significantly positively correlated with enterprise performance, supporting H1. In other words, the higher the R&D intensity of an enterprise, the better the enterprise performance.

2) Test of the moderating effect of the complexity of value perception on the relationship

between the R&D intensity of AI companies and the enterprise performance

As shown in Table 2, in Models (3), it can be seen that the interaction terms of R&D of an enterprise and complexity of value cognition are significantly negatively correlated, which indicates that the complexity of value cognition has a negative moderating effect on the relationship between the R&D intensity of an enterprise and enterprise performance, supporting H2.

3) Test of the moderating effect of the pressure of the market competition on the relationship between the R&D intensity of AI companies and the enterprise performance

In Models (4), it can be seen that the interaction terms of R&D intensity of an enterprise and the pressure of the market competition are significantly negatively correlated, which indicates that the pressure of market competition has a negative moderating effect on the relationship between R&D intensity of an enterprise and enterprise performance, supporting H3.

Table 2: Stratified regression analysis results.

	M(1)	M(2)	M(3)	M(4)
Size	-0.131 (-0.83)	-0.202 (-1.15)	-0.154 (-0.86)	-0.233 (-1.38)
LEV	-1.914*** (-5.83)	0.296** (2.38)	0.289* (2.14)	0.277* (2.13)
SOE	0.182* (2.02)	-1.190*** (-3.54)	-0.747 (-1.73)	-1.032** (-2.46)
CEO	0.211 (1.82)	0.208** (3.04)	0.240*** (3.73)	0.193** (2.69)
SLK	-0.009*** (-6.89)	-0.012*** (-4.96)	-0.013*** (-8.70)	-0.018*** (-4.33)
Constant	-382.989 (-1.56)	5.003 (1.39)	4.326 (1.15)	5.555 (1.63)
RD		2.537* (2.01)	3.535** (3.35)	2.622* (2.05)
NC			-0.130*** (-3.77)	
RD_NC			-0.578*** (-4.29)	
HHI				0.529** (3.17)
RD_HHI				-8.921*** (-5.89)
Year	Controlled	Controlled	Controlled	Controlled
IND	Controlled	Controlled	Controlled	Controlled
ΔR ²	0.136	0.361	0.379	0.380
F	15.51	16.74	15.92	15.62

Notes: * p<0.1, **p<0.05, ***p<0.01.

4.3 Robustness Test

In order to improve the robustness of the conclusion, this paper tested the robustness with the following method. In previous related literature, the enterprise growth rate was used as the control variable instead of the asset-liability ratio (XIAO 2016). Therefore, this paper replaced the asset-liability ratio (LEV) with

the enterprise growth rate (Growth) (the difference between the main operating revenue of the current period and the previous period/the main operating revenue of the previous period). All test results are consistent with the original results.

5 RESEARCH CONCLUSION AND INSPIRATION

5.1 Research Conclusion

From the perspective of innovation theory and value cognition, this paper empirically analyzes and tests the influence of R&D intensity of an enterprise on enterprise performance and the regulatory effect of the complexity of value cognition and market competition, and comes to three conclusions. The R&D intensity of AI enterprises has a positive impact on enterprise performance; the complexity of value cognition has a negative regulatory effect on the relationship between the R&D intensity and performance of AI enterprises; the pressure of market competition has a negative regulatory effect on the relationship between R&D intensity and performance of AI enterprises.

5.2 Theoretical Contribution and Practical Significance

Firstly, in the field of AI, there are few studies on the relationship between R&D intensity of an enterprise and enterprise performance. This paper explored the relationship between them through the innovation theory and expanded the application of the innovation theory. It provided some theoretical basis for the improvement of enterprise performance by AI enterprises through R&D and innovation.

Secondly, there is no research in which the complexity of value cognition is considered as a situational variable to study its influence on the R&D intensity and performance of AI enterprises. To make up this gap, in-depth research from the perspective of value cognition was done. In the context of the high complexity of value cognition, it is difficult for AI enterprises to gather resources for R&D and innovation, so the enterprise performance cannot be improved in the short term. Therefore, when making R&D decisions, enterprise managers should prevent resources from being too fragmented and solve the problem of resource waste caused by excessive attention to the value chain.

Thirdly, AI enterprises are emerging technology enterprises. Under the high pressure of market competition, managers should not blindly increase R&D costs because of the decisions of competitors, which is a short-sighted behavior. If it is separated from the actual situation of the enterprise, the substantial increase in R&D costs will not only

increase sunk costs, but also will not help with the improvement of enterprise performance.

5.3 Limitations and Future Research

The following limitations of this study can be used as a reference for future research. First of all, since there were few listed companies of AI concept stocks from 2011 to 2019, in the end, only 75 enterprises were considered as samples, which is a relatively small sample size. In the future, we can conduct research based on more enterprise samples. Next, we only measure the R&D intensity of AI enterprises with financial resources, but other resources such as the R&D personnel and technology may also affect enterprise performance. The influence of different types of resources on enterprise performance should also be discussed in future researches. Last but not least, in this study, the text analysis method was used to measure the complexity of value cognition of managers of AI enterprises. There will be subjective factors of researchers.

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