The Impact of R&D Investment on the Innovation Capacity of China's Electrical Machinery Manufacturing Industry

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Abstract. China's machinery manufacturing industry is an important part of the country's manufacturing and processing industry. The improvement of technological research and development capabilities must be premised on the continuous increase of research and development funds and the number of R&D technical personnel, and then further influence the enhancement of innovation capabilities and core competitiveness. This study focuses on China's electrical machinery manufacturing industry, utilizing financial statement data and R&D investment data collected from 315 listed companies in the sector between 2019 and 2024 through the use of the Wind and CSMAR databases. Through the construction of a panel data model, from the perspective of R&D investment, analyze the main factors influencing the innovation capabilities of listed electrical machinery manufacturing enterprises in China. The fixed effects panel data analysis results indicate that explanatory variables, including R&D expenditure, firm size, and cash input capacity, exhibit a statistically significant and positively correlated relationship with enterprise innovation output. The correlation between the input of R&D personnel and the innovation ability of enterprises is not obvious, while the asset-liability ratio of enterprises shows a strong negative correlation with the innovation ability. According to the results of the empirical analysis, this paper further puts forward measures and suggestions for enhancing the innovation capacity of China's electrical machinery manufacturing industry.

Keywords: Electrical machinery manufacturing industry; Research and development investment; Innovation ability.

1. Introduction

For the research on the impact of R&D investment on the innovation capacity of enterprises, the main research perspectives involve whether there is a correlation between these two variables, the definition of the degree of correlation, the innovation of research methods and approaches, and conducting kinds of analyses by different industries. Hall took the innovation capacity of the domestic aviation machinery manufacturing industry in France as the research object. His research shows that the number of people and funds invested in research and development has a clear positive correlation with the innovation capacity of the French aviation machinery manufacturing industry [1].

Wakelin took the R&D investment in the UK's food processing machinery manufacturing industry as the research object. His research conclusion indicates that the growth rate of R&D investment shows a strong correlation with the output of developed products. There are many factors influencing R&D output, such as the funds invested in the R&D process, the types and quantities of personnel involved in R&D, the industry and type of the enterprise, and the enterprise's debt situation, etc [2].

Paulo took the technological research and development capabilities of domestic manufacturing enterprises in Germany as the research object, and the manufacturing enterprises in the country were classified into two main categories: technology-intensive and non-technology-intensive. The stepwise regression method in econometrics was employed to analyze the data, research, and analysis show that for high-tech enterprises, there is a strong positive correlation between R&D investment and the improvement of innovation capabilities. However, for non-high-tech enterprises, the growth of R&D investment does not significantly enhance their innovation capabilities [3].

In 2022, Chinese scholars Wang Xi et al. selected 576 manufacturing enterprises as the research sample and, by introducing mediating variables, studied the relationship among government funding, R&D investment, and the improvement of enterprises' innovation capabilities. Research shows that while government funding can sustainably support the growth of enterprise R&D investment, such investment significantly enhances the innovation capacity of the processing and manufacturing industry, thereby promoting a substantial increase in the output of innovative products [4].

Considering the significance of enhancing the innovation capacity of China's electrical machinery manufacturing industry, this study employs quantitative analysis, specifically linear regression analysis, to construct a panel data model that quantitatively examines the relationship between R&D investment and innovation capabilities of listed electrical machinery manufacturing enterprises in China. Through the empirical analysis process, factors with no obvious influence are eliminated, the factors affecting the innovation capacity of China's electrical machinery manufacturing industry are identified, and the magnitude of the influence is ranked according to statistical indicators. Based on the results of the empirical analysis, some suggestions for enhancing the innovation capacity of China's electrical machinery manufacturing industry are put forward.

2. Methods

2.1. Dataset

Based on China's information disclosure framework, this study collects and organizes key financial indicators of listed companies—including net profit, total assets, ending total assets, net cash flow, and total assets and liabilities—from the Wind database [5]. Collect and organize data such as the input of R&D personnel and the input of R&D funds through the Wind database for analysis [6]. The accuracy of data analysis directly affects the validity of the analysis. This paper excluded enterprises with negative return on total assets and missing statistical data on enterprise R&D and investment indicators during the period from 2019 to 2024. Through the above-mentioned data collection methods, sample data of 315 Chinese electrical machinery manufacturing enterprises were ultimately obtained. By using quantitative model analysis and statistical analysis methods, correlation statistical analysis and panel data regression model analysis were conducted on the sample enterprises. Through statistical test analysis, the influencing factors affecting the innovation capacity of China's electrical machinery manufacturing industry are evaluated, and the stability test of the analysis results indicated by the model is conducted.

2.2. Selection and Definition of Variables

2.2.1. The explained variable

1) Return on total assets (RTA)

In the selection of variables for innovation capabilities, the availability of data should be taken into account, and the practices of many scholars, such as Chinese scholar He Yingling, in setting indicators for the innovation capabilities of listed companies on the Growth Enterprise Market in 2022, should be drawn upon [7]. This article adopts RTA as the indicator to evaluate enterprise innovation capability. A higher RTA value indicates greater efficiency in enterprise asset utilization. The improvement of asset operation efficiency will inevitably lead to a significant enhancement in innovation capabilities. The formula for calculating the return on total assets is as follows

$$Return\ on\ total\ assets\ (RTA) = Net\ income/total\ assets \tag{1}$$

2) Tobin Q value (TBQ)

Return on total assets (RTA) can reflect an enterprise's recent innovation ability. The Tobin Q value (TBQ) can evaluate and estimate an enterprise's innovative development capabilities from a long-term perspective. The analysis in this paper is based on a combination of short-term analysis and long-term research. In the long term, using Tobin's Q value (TBQ) to analyze the innovation ability of listed companies has strong practical significance and value, and the Tobin's Q value is also a necessary explained variable for testing the stability of the model [8]. The formula for calculating the Tobin Q is as follows,

$$TBQ = Market\ value\ of\ the\ enterprise/replacement\ cost\ of\ the\ enterprise \quad (2)$$

2.2.2. Explanatory variables

This paper draws on the research of relevant scholars and takes into account the characteristics of electrical machinery manufacturing enterprises. It selects two relative quantity indicators, namely the proportion of R&D expenditure and the proportion of R&D personnel investment, as the explanatory variables of the model.

1) Proportion of research and development expenditure (RDF)

At present, most of the literature published by scholars studying the innovation capacity explains the influence of R&D investment on the innovation capacity of enterprises in terms of the intensity of R&D investment (RDF) [9]. This article also opts to adopt the relative indicator of R&D investment intensity. The intensity of R&D investment is quantitatively evaluated by the ratio of the amount of funds an enterprise invests in R&D to its total main business income.

2) The proportion of R&D personnel input (RDP)

The proportion of R&D personnel investment is another commonly used explanatory variable, defined as the ratio of the number of scientific and technological professionals and related technical staff engaged in R&D activities during product and technology development to the enterprise's total workforce [10].

2.2.3. Control variables

In addition to the two explanatory variables of R&D investment and R&D personnel investment, SCALE, Total debt ratio (TDR), and Cash input capacity (CIC) are used as control variables for the empirical model. These three variables may also have a significant impact on the improvement of the enterprise's innovation capacity. Adding these three variables for quantitative analysis can improve the accuracy of the model's interpretation [11-13].

2.2.4. Variable summary

Organize the above variables and draw Table 1, with the types, names, symbols and meanings of each variable as shown in Table 1.

Table 1. Names and symbolic meanings of Related variables.

Variable Types	Variable Name	Meaning
Explained variable	RTA	Net profit/total assets
	TBQ	Share price/market replacement cost
Explanatory variables	RDF	Research and development expenditure/operating income
	RDP	The number of R&D personnel/the total number of employees
Control variables	SCALE	Total assets at the end of the year
	TDR	Total liabilities/total assets
	CIC	Net cash flow/total assets

2.3. Model Construction

Based on the collection and collation of R&D investment data and related financial data, the following model is established,

$$RTA_{it} = a_0 + a_1 * RDF_{it} + a_2 * RDP_{it} + a_3 * SCALE_{it} + a_4 * TDR_{it} + a_5 * CIC_{it} + \varepsilon_{it} \quad (3)$$

Taking RTA as the output level of an enterprise's innovation ability, and R&D investment as the explanatory variable of the model, the level of R&D investment is measured from the perspectives of R&D personnel and R&D funds. The fundamental assumption is that there is a correlation between R&D investment and innovation ability in the electrical machinery manufacturing industry. RDF and RDP are explanatory variables for the model, while enterprise SCALE, total debt ratio TDR, and cash input capacity CIC are control variables.

In Equation (2) above, a_0 is a constant term; a_1, a_2, a_3, a_4, a_5 is the regression coefficient; ε_{it} is a random error term, .RTA_{it} with the subscript representing enterprise and time respectively, reflecting the innovation performance of the i-th enterprise in the t-th year, $,RDF_{it}$ and RDP_{it} representing the R&D investment and R&D personnel investment of the i-th enterprise in the t-th year respectively, and introducing three indicators $SCALE_{it}, TDR_{it}, CIC_{it}$, namely the enterprise size, asset-liability ratio, and cash investment capacity of the enterprise in the t-th year respectively.

3. Empirical Analysis

3.1. Correlation Analysis

In this paper, SPSS 26.0 software was used to conduct a correlation analysis of the above variables, as shown in Table 2:

Table 2. Correlation Test of Variables

	RTA	RDF	RDP	SCALE	TDR	CIC
RTA	1					
RDF	0.513264 *	1				
RDP	0.357826 * *	0.412232	1			
SCALE	0.687122 * *	-0.241129	0.352517 *	1		
TDR	0.477363 *	-0.479226	-0.311773	0.218237	1	
CIC	0.384193 * *	0.413382	0.398226	0.301191 *	0.366183 *	1

The correlation statistical analysis in Table 2 shows that the five variable indicators, namely R&D expenditure (RDF), the proportion of R&D personnel (RDP), enterprise SCALE (Scale), asset-liability ratio (TDR), and cash flow (CIC), all have significant correlations with the explained variable, namely return on total assets (RTA). There is a strong negative correlation between the asset-liability ratio (TDR) and the enterprise's innovation ability (RTA), while the four variables of research and development expenditure (RDF), the proportion of R&D personnel (RDP), enterprise SCALE (Scale), and cash flow (CIC) have a strong positive correlation with the enterprise's innovation ability (RTA).

From the horizontal comparative analysis of two explanatory variables and three control variables, it can be seen that the two explanatory variables, namely the RDF and the RDP, show a positive relationship. This can be interpreted as the fact that the investment in R&D by enterprises and the number of R&D personnel in enterprises follow a pattern of change in the same direction. Among the three control variables, the SCALE of the enterprise shows a positive correlation with the investment in R&D funds and the investment in R&D personnel and has passed the significance test at the 5% level. The asset-liability ratio (TDR) shows a negative correlation with RDF, RDP, and CIC. That is, the higher the asset-liability ratio. The enterprise's investment in research and development funds and personnel, as well as its ability to pay in cash, are relatively lower. However, the correlation with the SCALE of enterprises is not obvious.

3.2. Regression Analysis

3.2.1. Establish a random effects panel regression model

Using econometric software EViews 12.0, this paper initially constructs a random panel data model using panel data. The analysis results show that, first of all, the model passes the significance test of the equation, namely the f-test, and the five variables as a whole have a strong explanatory power for the explained variable RTA. The variables also passed the significance test of the variables, that is, the t-test. The adjusted goodness-of-fit value of the model was 0.671252, and the model also had a good fit (Table 3).

Table 3. Results of Random Effects Regression.

Variables	RTA
RDF	0.262532 * (3.787571)
RDP	0.577811 * * (8.115269)
SCALE	0.306118 * (12.797531)
TDR	13.353877 * * (7.949682)
CIC	4.117769 * * * (4.368187)
Constant	13.899626 (1.987793)
R-squared	0.681029
Adjusted R-squared	0.671252
F-statistic	125.463652
Prob(F-statistic)	0.000000

3.2.2. Hausman test for random-effects models

The panel data model needs to use the Hausmann test to determine whether the model belongs to a fixed-effects model or a random-effects model, so as to ensure the stability of the regression analysis results.

Table 4 presents the specific results of the Hausman test. The r-square value of the goodness-of-fit of the model is 0.485, indicating a good fit. Meanwhile, the calculated value of the F-test is 7.225217. Through the significance test, it is indicated that the relevant explanatory variables selected by the model are correlated with individual effects, that is, the fixed-effects model should be selected for analysis.

Table 4. Results of the Hausman test.

Effects Test	Statistic	Prob.
Cross-section F	7.225217	0.000000

3.2.3. Build a fixed effects model

Using the econometric software EViews 12.0, the regression coefficient of RDP is 0.025152, but it fails the significance test of the variable, indicating that under the analytical framework of the fixed effects panel data model, the investment of enterprise R&D personnel in RDP has no significant impact on the improvement of enterprise innovation ability RTA (Table 5).

Table 5. Analysis of the results of the fixed effects model.

Variables	Statistics
RDP	0.025152 (0.300719)
RDF	* * (8.595236 0.366323)
TDR	0.378215 * * * (7.517583)
CIC	* * (2.658752 1.178275)
SCALE	0.421856 * (2.528761)
R-squared	0.565539
Adjusted R-squared	0.533787
F-statistic	71.969325
Prob(F-statistic)	0.000000

t-statistics ***p<0.01,**p<0.05,*p< 0.1

Among the other explanatory and control variables, the negative impact of the asset-liability ratio (TDR) on RTA is significant, the negative impact of the asset-liability ratio (TDR) on RTA is significant, and the analysis conclusion here is consistent with the analysis of the random effects model in the previous text. The correlations between variables such as RDF, SCALE, and CIC and the explained variable RTA are also consistent with the conclusion of the random effects model mentioned earlier, that is, they show a positive correlation (Table 6).

Table 6. Analysis of F-test results.

Effects Test	Statistic	Prob.
Cross-section F	2.303682	0.000000
Cross-section Chi-square	43.278963	0.000000

3.2.4. Re-establish the fixed effects model

The explanatory variable RDP failed the test, so it was deleted, and the following regression equation was re-established.

$$RTA_{it} = 7.625629 + 0.287578 * RDF_{it} - 0.752575 * TDR_{it} + 1.200718 * SCALE_{it} + 3.872872 * CIC_{it} \quad (4)$$

Conclusions As shown in Table 7, the overall F-test of the model has an F-value of 5.993890 and a p-value of 0, indicating that the significance test at the 1% level indicates that there is at least one independent variable in the model that has a regression relationship with the dependent variable. The adjusted goodness-of-fit R-squared was 0.654670, indicating good explanatory power of the model. The t-test for significance of variables suggested that after excluding irrelevant variables, the significance P-values of all independent variables were less than 0.01, and the results of the statistical test indicated that the test was passed. From the coefficients of the regression results, it can be found that the coefficient of the explanatory variable RDF is 0.287578, showing a significant positive correlation. For every unit increase in RDF, the explanatory variable increases by 0.287578 units. The coefficient signs of the control variables TDR, SCALE, and CIC are consistent with the results suggested by the two models mentioned earlier.

Table 7. Statistical analysis results of the Fixed Effects model.

Variables	RTA
RDF	0.287578 * * * (8.336985)
TDR	-0.752575 ***(-6.188537)
SCALE	1.200718 * * * (9.141758)
CIC	3.872872 * * * (5.62857)
Constant	7.625629 * * * (6.515884)
R-squared	0.675730
Adjusted R-squared	0.654670
F-statistic	5.993890
Prob(F-statistic)	0.000000

t-statistics ***p<0.01 **p<0.05 *p<0.1

3.3. Robustness Test

Model robustness tests ensure that the results of variable analysis have long-term stability and validity. Following the basic paradigm of robustness tests, this paper reconstructs the panel data regression model by replacing the explained variable RTA with the Tobin Q value (TBQ), and the results of the re-implementation of the Hausman test are shown in Table 8. The results of the analysis are basically consistent with those before the replacement, whether in terms of the number of variables passing the t-test or the positive or negative values of the regression coefficients. The results of the F-test and goodness-of-fit test were also largely consistent, indicating that the analysis of the model passed the robustness test and that the analysis results suggested by the model were stable and valid over the long term.

Table 8. Robustness analysis of the model.

Variables	Model Re	Model Fe
RDF	0.262532* (3.787571)	0.049587* (1.198891)
RDP	0.577811** (8.115269)	0.0622577* (0.686697)
SCALE	0.306118 * (12.797531)	0.187749* (0.232371)
TDR	0.353877 * (7.949682)	-0.232587* (0.752155)
CIC	0.117769*** (4.368187)	0.0731176** (0.289961)
Constant	13.899626	19.747511
R-squared	0.681029	0.601930
Adjusted R-squared	0.671252	0.596074
F-statistic	125.463652	25.798513
Prob(F-statistic)	0.000000	0.000000

t-statistics ***p<0.01, **p<0.05, *p<0.1

4. Conclusion

Based on empirical analysis, the specific conclusions of this paper are as follows. There is a relatively clear positive correlation between the R&D expenditure of listed companies in China's electrical machinery manufacturing industry and their innovation capabilities. From the regression coefficient, the influence is relatively small. This is because although the total amount of R&D investment in China's electrical machinery manufacturing industry has increased year by year, the proportion has not significantly increased, resulting in the impact of R&D investment on the improvement of innovation capacity in China's electrical machinery manufacturing industry needs to be further improved.

Second, there is no significant correlation between the R&D personnel investment in listed companies within China's electrical machinery manufacturing industry and their ultimate innovation output. This indicates that the proportion of R&D personnel has increased significantly, but the contribution of R&D personnel to the improvement of innovation capabilities has not been significantly reflected. The possible reasons are that enterprises do not attach enough importance to R&D personnel, do not pay enough attention to the working environment of R&D personnel, and do not significantly improve the salary and benefits of R&D personnel.

Third, among listed companies in China's electrical machinery manufacturing industry, there is a significant positive correlation between cash holdings, firm size, and innovation output indicators. The regression coefficient of TDR is negative, passing the significance test. Therefore, if enterprises want to achieve long-term economic benefits, they also need to address problems such as insufficient cash strength and high debt-to-asset ratio.

This study is subject to certain limitations, the most prominent of which pertains to the determination of data stationarity. Due to issues such as the scale of data collection itself, the problem of multicollinearity of variables has not been eliminated to a certain extent, thus having an impact on the current quantitative data analysis results. In subsequent studies, explanatory variables will be further added and multicollinearity will be eliminated. To enhance the precision and reliability of the research findings.

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