

The Impact of Research and Development Expenses on Operating Revenue

Jinxuan Liu*

Department of Arts & Science, Queen's University, Kingston, Canada

* Corresponding Author Email: 19jl46@queensu.ca

Abstract. With the advancement of technology and the development of the knowledge economy, the improvement of enterprise research and development capabilities has become a key factor in promoting enterprise competitiveness and economic growth. This study takes Chinese manufacturing enterprises as an example to explore the impact of the number of R&D personnel and R&D investment costs on operating income. Using the two-stage least squares (2SLS) model and the industry dataset for analysis, the study found that as the number of R&D personnel increased, R&D investment costs increased, significantly increasing the company's operating income. Although the model has limitations such as industry limitations, spatial limitations, and variable limitations, the research results still emphasize the positive impact of R&D investment on the economic benefits of enterprises. The study also provides suggestions on how to improve research accuracy and how to enhance enterprise research and development capabilities. Finally, it is concluded that improving R&D capabilities and allocating R&D investment reasonably are of great significance for manufacturing enterprises, which will help improve the company's operating revenue and overall competitiveness.

Keywords: Two-Stage Least Squares (2SLS), Research and Development (R&D) Investment; Manufacturing Industry.

1. Introduction

Against the backdrop of economic globalization and rapid technological development, various enterprises are facing increasingly fierce competition. In this environment, enterprises' research and development (R&D) investment has become an essential factor determining their market competitiveness and even survival. R&D investment refers to the cost that a company invests in the innovation of new products, technologies, or services to obtain economic benefits in the future. The company's emphasis on research and development investment has gradually increased in the past few decades. Whether it is a technology giant in Silicon Valley or a small startup, the proportion of research and development expenses in the company's operating capital has continued to grow. R&D is crucial for the development of manufacturing companies. With the continuous development of technology and changes in market demand, enterprises can only maintain synchronization and competitiveness with the market by continuously developing new products or improving existing products. Product innovation can improve product performance, add new features, improve user experience, and even open up innovative markets. R&D is not limited to products but also includes production processes and technologies. By developing new production technologies and processes, production efficiency can be improved, production costs can be reduced, and the company's profitability can be improved. In addition, studying the impact of R&D investment on revenue is also essential for manufacturing companies. By understanding the relationship between R&D expenses and revenue, manufacturing companies can more effectively allocate resources and manage R&D projects, thereby achieving the best balance between input and output while ensuring R&D quality. Studying their relationship can also reveal industry development trends and competitive patterns, helping companies make more forward-looking strategic decisions.

This paper uses two-stage least squares regression to test the impact of research and development expenses on the revenue of Chinese manufacturing companies. This study uses China's Panel data to estimate the impact of the number of R&D personnel on the company's R&D expenses and the impact on the company's turnover. This article uses 15 years of panel data because panel data can better

capture the relationship between variables. In addition, the robust standard error is used in this paper to control the heteroscedasticity, which helps to reduce the error and make the estimation result more reliable.

1.1. Literature Review

Over the past five years, numerous researchers have delved into the relationship between the number of R&D personnel and the cost of R&D investment. One such study employed a difference-in-differences approach to examine the influence of the additional deduction policy for R&D expenses on corporate R&D input, finding a significant stimulative effect. The study conducted a regression analysis on the 'ratio of R&D investment to operating revenue' and the 'logarithm of the number of R&D personnel', uncovering a significantly positive correlation between the two [1]. In parallel, other researchers investigating the impact of R&D subsidies on R&D input discovered that public R&D subsidies have boosted total R&D input represented by the total number of R&D personnel. An increase in R&D subsidies by one standard deviation reduces private R&D expenditures of large and medium-sized industrial enterprises by 6.5% but increases their total number of R&D personnel by 2.6% [2]. Another line of research found that in the gaming industry, more experienced R&D personnel can aid enterprises in enhancing innovation efficiency, thus encouraging increased R&D investment [3]. Additionally, a study analyzing the impact of R&D in the Turkish manufacturing industry on product and process innovation indicated that although an increase in the number of R&D personnel leads to increased R&D investment costs, it can also lead to greater innovative output [4].

Many researchers also have studied the relationship between R&D investment costs and operating revenue. One study used a mediating effect model to investigate the relationship between corporate performance and R&D input, revealing an inverted U-shaped relationship where the impact on R&D input strengthens before weakening [5]. Further studies have utilized multivariate linear regression models for empirical analysis, finding that data-driven enterprises' R&D input positively impacts operational performance, with the effect showing significant latency, particularly in the second lag period [6]. Another study focusing on the lagged impact of R&D input on corporate performance found that R&D input negatively impacts current and first-lag period corporate performance but positively impacts the second-lag period performance [7]. Moreover, research using a stepwise regression method to analyze factors affecting operating revenue and R&D input revealed that operating revenue can significantly improve R&D input and identified a mutual dependency between the two [8]. Another group employed a fixed-effects model and a two-stage least squares (2SLS) model to study the impact of R&D investment on Vietnamese corporate performance. They found that the higher a company's R&D investment costs, the higher its profits, revenue, and asset return [9]. Lastly, some researchers employed a dynamic panel data model for empirical analysis of the impact of R&D intensity on corporate performance, determining that R&D investment in high-tech industries has positive and lagged effects and is positively correlated with business performance [10].

Although various statistical and econometric methods are used in these studies, these methods have limitations in addressing endogeneity issues, affecting the accuracy and reliability of research results. Moreover, most of these studies have a relatively short time span, which may lead to a situation where the observed relationships need to reflect long-term effects adequately. Therefore, this paper will use the 2SLS model to analyze enterprises' operating revenue and R&D input cost and add advertising expenditure, net profit, operating cost, and a series of control variables into the model to establish a Panel data model. Comprehensively analyze the data of all manufacturing listed companies in China from 2007 to 2021 and draw corresponding conclusions.

1.2. Overview of Research

Based on the empirical research above, two primary relationships can be found. First, it is observed that the number of R&D personnel positively impacts the company's R&D expenses. Secondly, it is found that there is a positive correlation between the company's R&D investment and its turnover.

These results are consistent with previous literature and what was expected before this study was completed, reinforcing the thesis that a company's R&D investment positively impacts its turnover.

The structure of this paper is as follows: The second section describes in detail the analytical methods used, including the selected data and models. The third section presents the results of the econometric model. The fourth section discusses the research limitations and recommendations on how Chinese manufacturing enterprises can optimize R&D investment and increase turnover. Finally, the fifth section will summarize the main findings and conclusions of the whole study.

2. Methods

2.1. Data

In order to assess the impact of R&D investment expenses on turnover, this paper performed a two-stage least squares regression using data from China. The focus of the analysis is on the data of Chinese manufacturing listed companies from 2007 to 2021 because these 15 years are an important stage of China's economic and technological development, during which many companies began to attach importance to research and increase investment in research and development, which can provide an ideal environment for research. These data are mainly from two major databases. The Guotai 'an database provides financial data including operating revenue, R&D investment expenses, net profit and operating costs. The Wind database provides information on the company's advertising expenses and the number of research and development personnel. The descriptive statistics for each imported data variable are summarized in Table 1.

Table 1. Descriptive Statistics

Variable	N	Mean	SD	Min	Max
OR	23896	6.448	23.697	0	887.626
RD	23896	0.181	0.682	0	20.595
NRDS	23896	0.061	0.182	0	4.038
AE	23896	0.035	0.33	0	13.572
NP	23896	0.376	1.766	-46.662	55.721
OC	23896	5.167	20.421	0	769.986

Variables such as operating income, R&D investment expenses, number of R&D personnel, advertising expenses, net profit, and operating costs represent the different economic situations of the company and are evaluated using numerical measures. Table 1 shows that the minimum value of operating revenue is 0, the maximum value is 88.7626 billion RMB, and the average value is 644.8 million RMB. This reflects the low operating revenue of most manufacturing companies and the significant differences in revenue scale among manufacturing companies. The minimum value of the R&D investment cost is 0, the maximum value is 2.0595 billion RMB, and the average value is 0.182 hundred million RMB. This shows the differences in R&D investment among different types of companies and the relatively low R&D investment of most companies. The average number of R&D personnel is 0.061 ten thousand, which means that in most listed companies, the size of the R&D team is relatively small. The average advertising expenditure is 0.035 hundred million RMB, indicating that the advertising investment of most listed companies is also relatively low, as well as the differences in advertising investment and marketing strategies among different companies. The minimum net profit is -4.6662 billion RMB, the maximum value is 5.5721 billion RMB, and the average value is 0.376 hundred million RMB, reflecting the significant differences in profitability among Chinese manufacturing companies. The average operating cost is 5.167 hundred million RMB, indicating that most listed companies have low operating costs and significant differences in operating cost control among different companies.

2.2. Robustness Test

To ensure that there is no severe multicollinearity between explanatory variables, the VIF test is performed on the variables. Table 2 shows a VIF of 2.89 for operating costs, 2.19 for R&D investment expenses, 1.86 for net profit, and 1.41 for advertising expenses. All VIF values are significantly lower than 5, indicating no severe Multicollinearity problem between explanatory variables. Therefore, it can be concluded that the regression model is robust.

Table 2. Multicollinearity Test

Variable	VIF
OC	2.89
RD	2.19
NP	1.86
AE	1.41

2.3. Issue of Heteroscedasticity

According to descriptive statistics, the value of the independent variable changes in an extensive range, which is likely to lead to heteroscedasticity. After the Breusch Pagan test, Table3 shows that there was heteroscedasticity in the model because the P value was far less than 0.05. The original hypothesis was rejected. In the case of heteroscedasticity, the Standard error of Ordinary Least Squares (OLS) may be incorrectly estimated. This may lead to bias in the significance test of coefficients and the estimation of confidence intervals for regression coefficients, thereby affecting the model's accuracy. This article will provide an accurate standard error estimate using robust common errors, enabling the model to perform more precise significance testing.

Table 3. Breusch–Pagan Test for Heteroskedasticity

H0: Constant variance
chi2(4) = 2164.48
Prob > chi2 = 0.0000

2.4. Issue of Endogeneity

Through the Hausman test, Table 4 shows that there is a significant difference in the coefficients of the four variables "R&D investment expenses", "advertising expenses," "net profit," and "operating costs" in the fixed effects model and the random effects model. The value of the test statistic chi2 is 1376.52, and the corresponding P-value is much less than 0.05. Therefore, rejecting the original hypothesis and determining that the model has endogeneity issues. Endogeneity issues can lead to estimation coefficient bias, thereby affecting the interpretation and prediction of the model. To solve the endogeneity problem, this article will use Instrumental variables estimation. The Instrumental variables estimation needs to meet two basic conditions: it is independent of the model's error term and has a strong enough correlation with the interpreted variable. In order to ensure that the estimation of the Instrumental variable is effective, this paper conducts a weak Instrumental variables estimation test. Table 5 shows that the F-statistic is 13610.3, which is much higher than the 10% standard. This means that the selected Instrumental variables estimation "number of R&D personnel" has a strong enough correlation with "R&D investment cost," there is no problem with weak Instrumental variables estimation. An unbiased and consistent estimation result can be obtained using Instrumental variables estimation.

Table 4. Hausman test

Test of H0: Difference in coefficients not systematic
chi2(4) = 1376.52
Prob > chi2 = 0.0000

2.5. Model

A This paper will use the 2SLS model to reduce potential biases due to interactions between variables. Two regressions are used in the model. The first regression evaluates the relationship between the number of R&D personnel and the dependent variable, R&D investment expense when the variables such as advertising expenditure, net profit, and operating cost are controlled. The second regression relates the estimated R&D investment expense in regression (1) to the dependent variable - operating revenue - and gives the control variables of advertising expenditure, net profit, and operating cost.

In the regression, RD_{it} represents the R&D investment cost of the company i in year t . OR_{it} represents the operating revenue of the company i in year t . $NRDS_{it}$, AE_{it} , NP_{it} , and OC_{it} represent the number of R&D personnel, advertising expenditure, net profit, and operating cost of the company i in year t , respectively. RD_{it_hat} represents the predicted value of R&D investment expenses obtained in the first stage regression and used for the second stage regression. The ε_{it} represents the error term that represents the effect of all factors not accounted for by the model.

$$RD_{it} = \alpha_0 + \alpha_1 NRDS_{it} + \alpha_2 AE_{it} + \alpha_3 NP_{it} + \alpha_4 OC_{it} + u_{it} \quad (1)$$

$$OR_{it} = \beta_0 + \beta_1 RD_{it_hat} + \beta_2 AE_{it} + \beta_3 NP_{it} + \beta_4 OC_{it} + \varepsilon_{it} \quad (2)$$

To address the collinearity issue, all critical variables, such as R&D headcount, advertising spend, net profit, and operating costs, are included in the analysis model, and none are excluded. Using the two-stage least squares method (2SLS) to eliminate potential endogeneity bias, a comprehensive evaluation is conducted on the impact of the increase in R&D investment costs caused by the increase in R&D personnel on the company's operating revenue.

3. Results

The relationship between the number of R&D personnel and R&D investment costs and their impact on revenue is shown in Table 5 (I) and Table 5 (II). Table 5 (I) presents the OLS regression in the 2SLS model, which shows the correlation between the number of R&D personnel and other continuous variables and R&D investment costs. The Instrumental variables estimation is the number of R&D personnel. The results indicate that the number of R&D personnel has the most significant impact on R&D investment costs. For every 10000 additional R&D personnel, the R&D investment expenditure is expected to increase by 1.878 billion RMB, while the rest remains unchanged. That is to say, for every additional R&D personnel, the R&D investment cost increases by 187781.2 RMB. The positive correlation between them follows the prediction in this article, but unexpectedly, R&D personnel will increase such a significant R&D investment cost. This may be because the salaries of R&D personnel are often higher than those of ordinary employees, and the company not only needs to pay their wages but may also need to purchase equipment and other necessary experimental materials for them to carry out their research and development work. In addition, increasing R&D personnel may also bring additional indirect costs, such as personnel recruitment and training costs. For other variables, net profit and operating costs positively impact R&D investment expenses. For every 100 million RMB increase in net profit, R&D investment expenditure is expected to increase by 0.04 billion RMB, while others remain unchanged. For every 100 million RMB increase in operating costs, R&D investment expenditure is expected to increase by 0.013 billion RMB, while others remain unchanged. Advertising expenses have a negative impact on research and development investment costs. The coefficient of advertising expenditure is -0.078, indicating that for every 100 million RMB increase in advertising expenditure, research and development investment expenses are expected to decrease by 0.078 billion RMB, while others will remain unchanged. The relationship between these three control variables and the dependent variable is consistent with the prediction because net profit is the remaining income of the company after paying all expenses. If the net profit

increases, the company may have more funds available for reinvestment, some of which may be used for research and development. This is because Research & Development is seen as a long-term investment that can help companies maintain competitiveness in the future. In addition, the increase in operating costs is primarily due to the company expanding its operational scale. As the scale grows, the company will increase its research and development investment to find new efficiency improvement methods or market opportunities. The increase in advertising expenses has led to a decrease in research and development investment costs, mainly because most companies have limited budgets. When advertising expenses increase, it is necessary to squeeze out funds from research and development to meet advertising expenses. The p-values of all variables in the model are less than 0.05, which means that all independent variables have statistical significance for the dependent variable.

Table 5. Two-Stage Least Squares (2SLS) Regression Output

VARIABLES	(I) first stage RD	(II) second stage OR
AE	-0.078*** (0.009)	1.063*** (0.033)
NP	0.040*** (0.002)	1.308*** (0.007)
OC	0.013*** (0.000)	1.013*** (0.001)
NRDS	1.878*** (0.016)	
RD_hat		2.391*** (0.032)
Constant	-0.014*** (0.003)	0.250*** (0.009)
Observations	23,896	23,896
R-squared	0.709	0.997
IV F-stat		13610.3

Standard errors in parentheses

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

Table 5 (II) shows the regression results of 2SLS regression (2). Using estimates from OLS regression and controlling variables such as advertising expenses, net profit, and operating costs, the revenue is regressed to R&D investment expenses_hat. The results indicate that through the use of sample data, R&D investment expenses have a positive impact on the company's revenue. From Table 5 (II), it can be seen that the coefficient of R&D investment expenses is 2.391, indicating that for every 100 million RMB increase in R&D investment expenses, while keeping other variables unchanged, the operating income will increase by 2.391 billion RMB. This shows a positive correlation between R&D investment and operating revenue, which is consistent with predictions, as increasing R&D investment will lead to improved product quality and innovation capabilities, giving the company a competitive advantage, attracting more customers, and increasing operating revenue. In addition, the coefficient of net profit is 1.308, which means that for every 100 million RMB increase in net profit, while keeping other variables constant, operating revenue will increase by 1.308 billion RMB. The coefficient of operating costs is 1.013, indicating that for every 100 million RMB increase in operating expenses, while keeping other variables constant, the operating revenue will increase by 1.013 billion RMB. Net profit and operating costs are positively correlated with turnover, consistent with predictions, as higher net profit typically reflects a company's higher product or

service quality, higher operational efficiency, or better cost management. These factors may attract more customers, leading to an increase in revenue. In addition, most companies will increase production costs to improve product quality or increase marketing costs to attract more customers. These cost inputs will give the company an advantage in competition, increase sales, and thus increase operating revenue. Advertising expenses are also positively correlated with revenue, consistent with predictions. The coefficient of advertising expenditure is 1.063, indicating that keeping other variables unchanged, for every 100 million RMB increase in advertising expenditure, the operating revenue will increase by 1.063 billion RMB. Effective advertising can increase consumers' awareness of brands and products. The higher the familiarity with a product or service, the higher the likelihood that consumers will purchase it. Advertising can also effectively convey information about products or services to potential consumers, helping them understand the advantages and characteristics of the product, thereby increasing their willingness to purchase. The P-values of all four variables are far less than 0.05. So, these variables and samples are statistically significant.

4. Discussion

4.1. Limitations

The model in this article conducts in-depth research on the relationship between operating revenue, R&D investment expenses, advertising expenses, net profit, and operating costs of manufacturing companies, and the results are statistically significant. However, it does have some limitations. Firstly, there are industry limitations to the model. The model in this article only focuses on manufacturing companies, and the research results do not have universality. Other industries' business models and profit sources may differ significantly from those of manufacturing. In order to increase the universality of the model, it can be attempted to expand the research scope to other industries, such as the service industry, agriculture, or high-tech industry. By comparing results across different industries, a clearer understanding can be obtained regarding which factors are universal and which ones are specific to certain industries. Secondly, the model has spatial limitations. The data source of this model is mainly Chinese companies, so that the model results may be affected by the specific economic, legal environment, and culture of the region, which may limit its applicability in other areas or internationally. Expand the research scope to other regions or countries. This can help us understand the impact of geographical, legal, economic, and cultural environments on research results. Thirdly, the model has restrictions on variables. Although the control variables considered in this model are essential, other control variables may have yet to be considered, such as the company's market share, corporate culture, quality of management teams, policy environment. These variables may have a significant impact on operating income. If carried out again, the article will include these variables and a broader range of variables. Although this may increase the complexity of the model, it can also provide a more comprehensive analysis.

4.2. Recommendations

Research and development capabilities are crucial for the development of enterprises, especially in today's rapidly changing era where continuous innovation and optimization have become a necessary condition for the survival and development of enterprises. Based on the above research findings, there are two suggestions that can help manufacturing enterprises strengthen their research and development capabilities. The results show that R&D investment has a significant positive impact on business revenue. Therefore, the first suggestion is that enterprises attach importance to research and development investment while optimizing the structure of research and development expenditure to ensure that each investment can generate maximum value. Invest more resources in projects with long-term development potential while focusing on projects with quick returns on research and development results. Amazon is a great example. Amazon has invested heavily in research and development. But Amazon is not mindlessly investing in research and development but optimizing its research and development investment structure. Amazon invests in projects related to its core

business and with long-term development potential, such as the highly complex technical infrastructure used to support its e-commerce business, AWS, and Prime membership services. This enables Amazon to improve its product quality and services, increase customer retention, and thus increase its revenue through research and development investment [11]. In addition, advertising expenses also significantly impact operating income, but excessive reliance on advertising expenses may squeeze research and development investment. Therefore, the second suggestion is that companies balance advertising spending and research and development investment to ensure that both receive appropriate support. Coca-Cola is a great example. Coca-Cola has always invested heavily in advertising, which usually attracts widespread public attention. At the same time, Coca-Cola also values research and development investment and has been developing new products and improving existing ones. This balance allows Coca-Cola to maintain brand awareness while developing new products to increase revenue [11].

5. Conclusion

This paper demonstrates the relationship between the number of R&D personnel, R&D investment costs, and revenue. Using the dataset of Chinese manufacturing companies and the 2SLS model, it is shown that as the number of R&D personnel increases, the R&D expenses invested by the company increase, and as the R&D expenses increase, the revenue also increases. These results are consistent with existing literature research.

This article also analyzes three limitations of the model, including industry limitations, spatial limitations, and variable limitations. Despite the model's limitations, the research results fully describe how R&D investment costs affect revenue. This article also provides corresponding suggestions for these limitations. Applying these suggestions can improve accuracy in future research. In addition, this article also proposes two recommendations that can enable manufacturing companies to enhance their research and development capabilities. The examples of Amazon and The Coca-Cola Company show the effectiveness of these two suggestions.

In the future, it is hoped that such research could be expanded to encompass more industries and broader geographical areas, allowing for a more comprehensive exploration of the impact of R&D expenditure on corporate economic benefits. At the same time, it is also desired to introduce more related variables to deepen the understanding of the relationship between R&D investment and corporate economic benefits, thus providing a more accurate and scientific basis for corporate decision-making.

References

- [1] Li Xin, Tang Hengyun, Tao Dongjie & Sun Xiaojun. Research on the Impact of R&D Expense Deduction Policy on Enterprise R&D Investment - Evidence from Chinese Listed Companies. *Macroeconomic Research*, 2019, (8), 81-93.
- [2] Boeing, P., Eberle, J., & Howell, A. The impact of China's R&D subsidies on R&D investment, technological upgrading and economic growth. *Technological Forecasting and Social Change*, 2022, 174, 121212.
- [3] Xi, X., Xi, B., Miao, C., Yu, R., Xie, J., Xiang, R., & Hu, F. Factors influencing technological innovation efficiency in the Chinese video game industry: Applying the meta-frontier approach. *Technological Forecasting and Social Change*, 2022, 178, 121574.
- [4] AKINCI, A., & VERGİL, H. Effect of R&D on Product and Process Innovation in the Turkish Manufacturing Industry. *Beykent Üniversitesi Sosyal Bilimler Dergisi*, 2023, 16(1), 8-25.
- [5] Huang Wenju & Shi Jinping. Research on the Impact of Enterprise Performance on R&D Investment: An Intermediary Model Based on Earnings Management. *Science and Technology Entrepreneurship Monthly*, 2021, 34 (9), 26-32.

- [6] Yue Yujun & Meng Miao. Research on the impact of R&D investment on the business performance of data-driven enterprises. *Journal of Beijing Jiaotong University (Social Science Edition)*, 2022, 21 (01), 94.
- [7] Li Yun. Research on the Relationship between R&D Investment and Enterprise Performance - Taking Listed Companies on the Science and Technology Innovation Board as an Example. *Advances in Social Sciences*, 2021, 10, 2689.
- [8] Li Shan. Research on the Interdependence between Operating Income and R&D Investment - An Empirical Analysis Based on Listed Companies on the Science and Technology Innovation Board *Economic Research Guide*, 2020, (36), 5.
- [9] Tung, L. T., & Binh, Q. M. Q. The impact of R&D expenditure on firm performance in emerging markets: evidence from the Vietnamese listed companies. *Asian Journal of Technology Innovation*, 2022, 30(2), 447-465.
- [10] Chen, T. C., Guo, D. Q., Chen, H. M., & Wei, T. T. Effects of R&D intensity on firm performance in Taiwan's semiconductor industry. *Economic research-Ekonomska istraživanja*, 2019, 32(1), 2377-2392.
- [11] Mathews, M. Winning Marketing and Business Strategies in a Highly Competitive and Globalized Economic Environment: A Case Study of Fortune 500 companies—Coca-Cola, Microsoft and Amazon. *MS Ramaiah Management Review ISSN (Print)-0975-7988*, 2021,12(02).