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**Research Paper**

# The impact of R&D innovation in biological vaccine industry on firm performance: the mediating effect of firm capability

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***ABSTRACT***
*The occurrence and expansion of COVID-19 has made countries around the world compete to invest in vaccine research and development. This paper uses panel data to analyze the impact of R&D and innovation on corporate performance in China's biological vaccine industry from 2007 to 2019, and analyzes the mediating effect with enterprise capability. The results show that the impact of R&D innovation on corporate performance through enterprise capability is the mediating effect of competitiveness, that is, the R&D innovation of the biological vaccine industry has a positive help to corporate performance, but is unable to increase the enterprise capability, but the overall effect is still conducive to the operation of the enterprise. In addition, this paper also found that the capital source of the biological vaccine industry must come from the owners themselves, and debt is detrimental to the performance of the company. In terms of corporate operations, the biologic vaccine industry should emphasize capital construction and marketing investment is detrimental to corporate performance.*

***KEYWORDS:*** *R&D; Mediation; Biological vaccine*

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## I. INTRODUCTION

The outbreak and expansion of COVID-19 at the end of 2019 has led to a scramble for vaccine research and development across the world. The ability of R&D and innovation has become an indicator of vaccine production. As for enterprises, whether R&D ability has a favorable impact on their business performance is also the main research direction of most recent scholars. Therefore, this paper aims at the analysis of the impact of new research and development on corporate performance in the vaccine-related industrial biological vaccine industry, and analyzes the mediating effect through the enterprise capability.

R&d impact on corporate performance has many scholars have confirmed that the conclusions are not consistent, a linear positive impact or negative impact, and even the influence of nonlinear, has also developed there is no significant relationship, and along with the progress of the statistical method, the research and development phase of the school also has a mediation effect on the company and the harmonic effect.

Research and development expenditure is very important to enterprises, but it is also very risky. If successful, research and development expenditure plays a very important role in creating the performance and value of enterprises. Branch (1974) found that R&D activities can lead to future sales growth rate and profit growth, and the company's profit, R&D expenditure budget and patent volume will lead to a relative increase in the company's future R&D income, which will lag one to four years due to industry differences. Morbey(1985) studied a total of more than 800 American enterprises during 1976-1985, whose annual R&D expenditure exceeded 1 million US dollars and sales volume exceeded 13 million US dollars, and found that across industries, R&D intensity had a significant positive relationship with corporate profits. Morbey and Reithner (1990) found that, regardless of the size of the company, R&D expenditure has a significant correlation with the company's

future revenue growth. Chan, Martin and Kensinger (1990) discussed the impact on stock prices when companies announced an increase in R&D expenditure budget, and found that there would be cumulative abnormal returns two days after the announcement, especially in high-tech industries. Hall (1993) pointed out that there was a significant positive correlation between R&D expenditure and firm performance. Sougiannis (1994) found that the R&D expenditure of an enterprise has a deferred effect, and the company's information can also be transmitted through the R&D expenditure. The results show that R&D expenditure or R&D intensity has a positive effect on firm value. However, the benefits may be deferred into the future. Szewczyk, Tsetsekos and Zantout (1996) found that for enterprises with large growth opportunities, the declared R&D expenditure would have a significant positive effect on the stock price, indicating that investors believed that the investment of R&D expenditure would have a positive effect on the development of the enterprise. Hill and Snell (1988) and Ayadi, Dufrene and Obi (1996) invest in R&D, which will bring future growth opportunities, long-term profits and increase the value of the company. The research of Hall and Bagchi-sen (2002) and Gongming and Li (2003) confirmed that the input of R&D expenditure has an impact on the value of the company. O'Brien (2003) believes that the higher the intensity of R&D expenditure, the more likely it is for the company to accumulate more technical capital and further improve the company's profits. The research of Connolly and Hirschey (2005) confirmed that the value of R&D expenditure to companies varies significantly with different sizes of companies. The value of each dollar of R&D expenditure invested by a larger company to Tobin 'Q is far greater than that of a smaller company. Tubbs(2007) discussed the relationship between R&D expenditure and enterprise performance, and the results proved that R&D expenditure was conducive to the improvement of the company's production capacity and service, thus promoting sales and improving corporate performance. Most subsequent studies have shown that the relationship is almost always positive (Hull and Rothenber, 2008; Yeh et. al., 2010; Alam et al., 2020 and Wei and Lin; 2021).

R&D investment is used as a source of competitive advantage, long-term growth and technological progress, which leads to better company performance (James and McGuire, 2016; Ruiqi et al., 2017; Patel, Guedes et al., 2018). However, some scholars pointed out that investment in research and development may not be able to meet the needs of the current period and thus have a negative effect on corporate performance (Chan et al., 1990; Liao and Rice, 2010; Knecht, 2013).

Lucas and Ayse (2018) point out that research and development (R&D) investment is regarded as the fundamental driver of high-tech small and medium-sized enterprise (SME) company performance. However, the same drivers may limit the growth of non-high-tech SMEs by increasing the level of risk faced by such companies. The results show that there is an inverted U-shaped relationship between R&D intensity and performance of non-high-tech SMEs.

Why the impact of R&D investment on corporate performance has been proved by scholars from irrelevant, linear positive and negative and non-linear results, and even the occurrence of mediating effects, and what the effect of the impact on the biological vaccine industry is the subject of this study.

The structure of this paper is as follows: The first part is Introduction, which mainly introduces the literature related to Research, R&D and innovation in this paper. The second part is Research Data and Research Method, which introduces the Research object and Method in this paper. This paper analyzes the impact of R&D and innovation on corporate performance in China's biological vaccine industry from 2007 to 2019, using panel data analysis and mediating effect analysis. The third part is the result of empirical analysis, and the last part is the conclusion. The research results show that R&D innovation has a positive impact on firm performance, but the short-term impact on firm capability is negative. Therefore, the impact of R&D innovation on firm performance through firm capability is the mediating effect of positive competitiveness.

## II. RESEARCH DATA AND RESEARCH METHOD

### 2.1 Research Data

This study examines innovation and innovation in the biofinine industry from eight biofinine companies in China from 2007 to 2019. A total of 99 biofinine companies per year and 87 biofinine companies per year with missing data were examined. All data sources were calculated from the annual reports published by the eight companies over a 13-year period and from this study.

### 2.2 Research Variable

This paper discusses the impact of R&D innovation on Corporate Performance, and three variables will be used in the variables. One is Independent variable (R&D intensity) and Dependent variable-corporate Performance. Mediation variables -- Company Capacity variables and Control variables are described below respectively

**(1) Independent variable - R&D intensity**

The R&D Intensity will mostly use the R&D expense ratio, i.e

$$RDI_{it}=\frac{RD_{it}}{S_{ti}}\times 100 \qquad (1)$$

$RDI_{it}$ : The R&D intensity of company I in phase T
$RD_{it}$:Research and development expenses of company I in period t
$S_{ti}$ : Company I's operating revenue for period t

However, in the econometric analysis, if the variable is taken as a natural number, it will be conducive to the interpretation of authenticity (the variable will be close to the normal distribution, and the coefficient after analysis is extremely economic elastic coefficient). Therefore, the natural logarithm of the measurement of R&D intensity is taken in this study, as follows

$$RDI_{it}=\ln\left(\frac{RD_{it}}{S_{ti}}\right) \quad (2)$$

H1a:RDI>0

**(2) Dependent variable -Corporate Performance (ROA)**

Tobin's Q is used by most scholars to measure corporate performance. The advantage of using Tobin's Q is that the quality of a company's operation is determined by the market, so Tobin's Q can also be called market performance. However, the price of China's stock market changes too much, and the stock price on that day is usually an abnormal value. Therefore, when studying corporate performance in China, many scholars will give up the measure of market performance and adopt organizational performance, namely ROA, and this study is no exception. The rate of return on total assets is measured as follows :

$$ROA=\frac{\text{Net interest rate before interest and tax}}{\text{Average total assets}}\times 100$$

The natural logarithm of this variable is also taken, modified as follows

$$ROA=\ln\left(\frac{\text{Net interest rate before interest and tax}}{\text{Average total assets}}\right)$$

**(3) Mediation variables**

In this example, capabilities are measured according to Jacobides(2013). The specific calculation method of capability is as follows:

$$TPF_{it}=\ln\left(\frac{Sale_{it}}{K_{it}^{\beta}\cdot L_{it}^{1-\beta}}\right) \quad (3)$$

Where, $\beta$ is the ratio of capital to GDP, Sale is income, K is tangible and intangible assets, and L is the number of employees.

Expected corporate capability is positively correlated with corporate performance

H1b:TPF>0

**(4) Control variables**

The control variables used in this study are marketing intensity (MAI), capital intensity (CAI), equity ratio (ER), and industrial competition degree (DIC).

The higher the growth rate of the company's assets, the more investment growth opportunities the company will have in the future (Agrawal and Knoeber, 1996; Titman and Wessels, 1988 and Wei et al., 2017), therefore, the growth of fixed assets is one of the business performance indicators of the company.

$$CAI_{it}=\ln\left(\frac{CA_{it}}{CA_{it-1}}\right) \quad (4)$$

CAit:Company I's non-current assets at period t

H1c: CAI>0

The marketing of a company is conducive to the corporate image, so the marketing expenditure is positively correlated with the market value of the company (Morck and Yeung,1991; Lu and Beamish, 2004; Shah, Stark, and Akbar,2009).

$$MAI_{it}=\frac{MA_{it}}{S_{ti}}\times 100 \quad (5)$$

$MAI_{it}$ : The R&D intensity of company I in phase T
$MA_{it}$:Research and development expenses of company I in period t

According to the corporate tax shield effect and the Pecking Order Theory, the higher the debt ratio, the lower the

earning rate and the lower the company value. (Myers, 1977; Stulz, 1990), but in this study, the natural logarithm of the equity ratio was used to calculate the liability ratio.

$$ER_{it} = \ln\left(\frac{\text{Total Debt}_{it}}{\text{Total Equity}_{it}}\right) \quad (6)$$

Biovaccines I can be used in the pharmaceutical, food and other industries, and the higher the level of competition, the better the ability of enterprises to improve. The degree of industry competition in this paper can be replaced by the concentration of Herfindal Index.

$$DIC=\Sigma(\text{Revenue ratio of all listed companies in the industry})2 \quad (7)$$

### 2.3 Descriptive Statistic

According to the above introduction of variables, there are a total of 7 variables in this study, and the descriptive statistics are shown in Table 1.

**TABLE 1 DESCRIBES THE STATISTICS**

| | ROA | RDI | CAI | ER | TFP | DIC |
|---|---|---|---|---|---|---|
| Observations | 87 | 87 | 87 | 87 | 87 | 87 |
| Mean | -2.44 | -11.58 | 0.22 | -0.58 | 14.11 | 5.48 |
| Median | -2.45 | -13.49 | 0.17 | -0.10 | 13.97 | 5.16 |
| Maximum | -0.48 | -2.28 | 2.81 | 1.94 | 15.95 | 7.84 |
| Minimum | -4.32 | -16.34 | -0.11 | -3.46 | 12.23 | 4.89 |
| Std. Dev. | 0.81 | 4.75 | 0.34 | 1.32 | 1.01 | 0.82 |
| Skewness | -0.09 | 0.94 | 5.29 | -0.64 | 0.05 | 1.78 |
| Kurtosis | 3.09 | 2.20 | 39.54 | 2.37 | 1.95 | 4.58 |

It can be found from Table 1 that the difference between the maximum and minimum values of the sample size in the study and the mean and the standard deviation are not significantly different (almost all within 3), indicating that there is no problem of outliers in the sample size in this study. In terms of distribution, ROA, SC and ER are skewed to the left, while others are skewed to the right. CAI and DIC are high gorge peaks, while RDI, ER and TFP are low width peaks.

### 2.4 Correlation Coefficient

The correlation coefficient matrix is mainly to avoid 2 highly correlated variables in the same equation. The correlation coefficient matrix of 7 variables is shown in Table 2.

**TABLE 2 CORRELATION COEFFICIENT MATRIX**

| | ROA | RDI | CAI | MAI | IC | ER | TFP |
|---|---|---|---|---|---|---|---|
| ROA | 1.00 | | | | | | |
| RDI | 0.13 | 1.00 | | | | | |
| CAI | 0.26 | -0.14 | 1.00 | | | | |
| MAI | -0.23 | 0.41 | 0.02 | 1.00 | | | |
| IC | -0.01 | -0.18 | 0.14 | -0.34 | 1.00 | | |
| ER | -0.53 | -0.04 | -0.03 | 0.15 | 0.24 | 1.00 | |
| TFP | 0.26 | 0.16 | 0.02 | -0.16 | 0.19 | -0.07 | 1.00 |

As you can see from Table 2, none of the seven variables presents a highly correlated problem.

### 2.5 Research Method

In this paper, the biological vaccine listed companies from 2007 to 2019 are studied, so the data of cross-section and time series are available, so the problems of single root and stationary will not occur like time series. However, for the sake of rigor of the study, the Levin, Lin & Chu Test is still used in this study to avoid the problems of single root. The stability of the data was analyzed by cointegration. After determining the stability of

the data, POOLED Analysis was used to determine whether the panel data in this paper was suitable for panel data Analysis.

Panel data analysis mainly has fixed effect and random effect. Fixed effect is usually fixed by time, while random effect is corrected by error term. Which effect is suitable for sample study, this paper adopts the Hausman Test proposed by Hausman(1978) in accordance with the research of most scholars?

Mediation was first used in the analysis of the relationship between social psychology and consumer behavior by Baron and Kenny (1986).

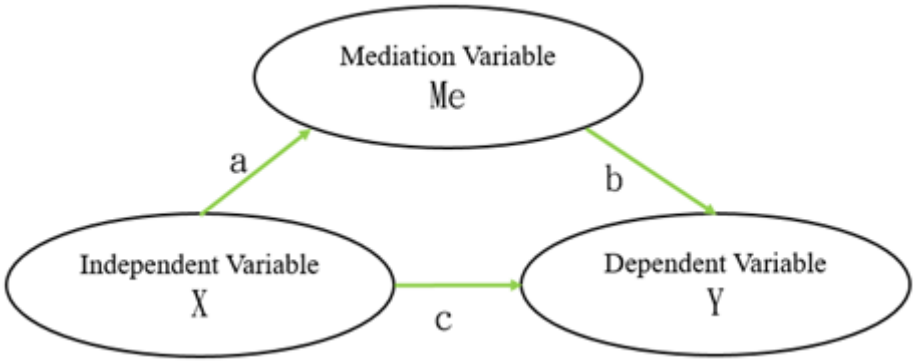


**FIGURE 1. MEDIATION EFFECT DEMONSTRATION DIAGRAM**

According to BK framework, three conditions need to be satisfied for variable M to play an "intermediary role" : the change of independent variable X should be able to significantly explain the change of undetermined intermediary variable M (path A is significant); The change of the intermediate variable M can significantly explain the change of the dependent variable Y (path B is significant); When paths A and B are controlled, the previously significant relationship between X and Y disappears (path C is not significant).

The BK framework believes that in order for the variable M to play a "mediation role", three conditions must be met: the change of the independent variable X should be able to significantly explain the change of the pending mediation variable M (path a is significant); the change of the mediation variable M can significantly explain the cause Changes in variable Y (path b is significant); after controlling paths a and b, the originally significant association between X and Y will disappear (path c is not significant) (as shown in Figure 1).

After the above variables and research methods are introduced, this paper establishes the research model as follows

$$ROA = \beta_0 + \beta_1 RDI + \beta_2 TFP + \beta_3 CAI + \beta_4 MAI + \beta_5 DIC + \beta_6 ER \quad (1)$$

$$TFP = \phi_0 + \phi_1 RDI + \phi_2 MAI + \phi_3 CA\ I + \phi_4 DIC + \phi_5 ER \quad (2)$$

Model (1) is the main model in this paper, and Model (2) is the mediating effect model.

## III. EMPIRICAL ANALYSIS

### 3.1Panel unit root test and stationarity test

In this paper, LCC was used to test whether the 7 variables had a single root. The results are shown in Table 3

**TABLE 3 SINGLE ROOT TEST OF STUDY VARIABLES**

| | ROA | RDI | CAI | MAI | DIC | ER | TFP |
|---|---|---|---|---|---|---|---|
| Statistic | -4.59 | -3.04 | -14.27 | -16.85 | -5.36 | -6.44 | -10.29 |
| Prob. | *** | *** | *** | *** | *** | *** | *** |

It can be seen from Table 3 that the variable does not have a single root problem.

Cointegration test. This paper used the Kao Residual Cointegration test, and the t-statistic was -2.92, P =0.00<0.05, indicating that there was co-integration in the research samples. The data is flat.

### 3.2Pooled Analysis

POOLED Analysis can be used to determine whether it is suitable for panel data Analysis by weighted and unweighted R2 and SSE. The POOLED Analysis results of the two models are shown in Table 4.

It can be seen from Table 4 that the R2 (0.34, 0.60) of weighted statistics of the two models is larger than that of unweighted (0.07, 0.41), and the SSE(71.82, 29.42) of weighted statistics is smaller than that of unweighted (81.26, 32.95). It means that the two models in this paper are suitable for Panel Data Analysis.

**TABLE 4POOLED ANALYSIS**

| | ROA | | TFP | |
|---|---|---|---|---|
| | Weighted | Unweighted | Weighted | Unweighted |
| R2 | 0.60 | 0.41 | 0.34 | 0.07 |
| SSE | 29.42 | 32.95 | 71.82 | 81.26 |

**3.3Panel Data Analysis**

In the introduction of 2.5, panel data analysis has fixed effect and random effect. Hausman Test can be used, and the Test results are shown in Table 5

**TABLE 5HAUSMAN TEST**

| Model | $\chi$ 2 Statistic | $\chi$ 2 d.f. | Prob. |
|---|---|---|---|
| ROA | 21.85 | 6 | (0.00) |
| TFP | 40.25 | 5 | (0.00) |

It can be seen from Table 5 that the P values of Hausman Test for the two models are all less than 0.05, indicating that the models are all suitable for the models with different adjustment effects. Therefore, we adopted the fixed effect for analysis, and the analysis results are shown in Table 6.

**TABLE 6 FIXED EFFECT**

| MODEL | (1) | | (2) | |
|---|---|---|---|---|
| Dependent | ROA | | TFP | |
| C | -4.44 | | 8.20 | |
| | (1.03) | *** | (1.29) | *** |
| RDI | 0.24 | | -0.40 | |
| | (0.08) | *** | (0.12) | *** |
| TFP | 0.30 | | | |
| | (0.08) | *** | | |
| CAI | 0.43 | | 0.09 | |
| | (0.20) | ** | (0.31) | |
| MAI | -0.23 | | -0.06 | |
| | (0.10) | ** | (0.16) | |
| ER | -0.18 | | -0.25 | |
| | (0.06) | *** | (0.10) | ** |
| DIC | -0.04 | | 0.18 | |
| | (0.09) | | (0.13) | |
| R-squared | 0.62 | | 0.40 | |
| F-statistic | 6.28 | | 2.68 | |
| Prob | *** | | *** | |

Note: "*", "**" and "***" indicate significant conditions at 10%, 5% and 1% significance levels respectively.
The model of the whole analysis is established from Table 6 as follows

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **ROA** | = | **- 4.44** | **+ 0.24RDI** | **+ 0.30TFP** | **+ 0.43CAI** | **- 0.23MAI** | **- 0.18ER** | **- 0.04DIC** | |
| | | **(1.03)** | **(0.08)** | **(0.08)** | **(0.20)** | **(0.01)** | **(0.06)** | **(0.09)** | **(1)** |
| | | *** * *** | *** * *** | *** * *** | *** *** | *** *** | *** * *** | | |
| **TFP** | = | **8.20** | **- 0.40RDI** | **+ 0.09CAI** | **- 0.06MAI** | **- 0.25ER** | **+ 0.18DIC** | | |
| | | **(1.29)** | **(0.12)** | **(0.31)** | **(0.16)** | **(0.10)** | **(0.13)** | | **(2)** |
| | | *** * *** | *** * *** | | | *** *** | | | |

According to the analysis model, it can be found that R&D innovation (RDI, 0.24), enterprise capability (TFP, 0.30) and capital intensity (CAI, 0.43) have significant positive effects on corporate performance, while marketing intensity (MAI,0.23) and equity ratio (-0.18) have significant negative effects. However, the degree of industry competition (DIC, -0.04) was not significant.

In the mediating effect model, RDI(-0.40) had a significant negative effect on FFP, and ER(-0.25) had a negative effect on TFP, while other variables were not significant.

Sobel Z test( $Z = \frac{a \times b}{\sqrt{b^2 s_a^2 + a^2 s_b^2}}$ )was used to determine the status of mediating effect

**TABLE 7 SIGNIFICANT MEDIATING EFFECT**

| Variable | Coefficient<br>Std. Error | Variable | Coefficient<br>Std. Error | Z | |
|---|---|---|---|---|---|
| TFP | 0.30<br>(0.08) | RDI | -0.40<br>(0.12) | -3.48 | *** |
| | | CAI | 0.09<br>(0.31) | 0.29 | |
| | | MAI | -0.06<br>(0.16) | -0.36 | |
| | | ER | -0.25<br>(0.10) | -2.57 | *** |
| | | DIC | 0.18<br>(0.13) | 1.31 | * |

In the final test of significant mediating effect, this paper can find out the current status of mediating effect of RDI, ER and DIC. The mediating effect of each variable on corporate performance through enterprise capability is as follows(Table 7):

1. Significant positive RDI, mediating effect, competitive mediating effect
2. ER is significantly negative, mediating effect, complementary mediating effect
3. DIC is not significant, mediating effect, complete mediating effect
4. CAI is significant and there is no mediating effect
5. MAI was significant and there was no mediating effect

**3.4Robustness test**

In this study 95% of the samples were examined. The results are shown in Table 8. The direction and significance of the effect of all explanatory variables on the explained variables are the same as in Table 6, so it means that the research is Robustness.

**TABLE 8 ROBUSTNESS TEST**

| MODEL | (1) | (2) |
|---|---|---|
| Variable | ROA | TFP |
| C | -3.45<br>(0.90) *** | 8.23<br>(1.35) *** |

| | | |
|---|---|---|
| RDI | 0.26 | -0.41 |
| | (0.07) *** | (0.12) *** |
| TFP | 0.23 | |
| | (0.07) *** | |
| CAI | 0.32 | 0.02 |
| | (0.18) * | (0.34) |
| MAI | -0.23 | -0.02 |
| | (0.09) ** | (0.18) |
| ER | -0.16 | -0.26 |
| | (0.06) *** | (0.11) ** |
| DIC | 0.00 | 0.19 |
| | (0.08) *** | (0.14) |

## IV. CONCLUSION

Under the new crown outbreak, countries all over the world come into vaccine research and development, research and development innovation ability become vaccine produced by major indexes, in terms of enterprise management, production of vaccines for the company's operating performance will have a very big help, based on financial index of biological vaccine research and development strength analysis of the influence of corporate performance. And combined with the panel data analysis and the intermediary effect to discuss.

The research results show that the R&D innovation of the biological vaccine industry has a significant positive impact on corporate performance, but the R&D investment should be sustained. In the short term, the R&D innovation has a negative impact on the ability of enterprises, but overall, the R&D innovation still has a positive impact on the performance of enterprises.

In addition to the analysis of R&D innovation, this paper also analyzes the situation of capital intensity and marketing intensity, and finds that the biological vaccine industry should focus on capital construction, but marketing investment is detrimental to corporate performance. Because the results of research and development are uncertain, the biovines industry is under pressure to finance itself through debt, preferably from the owners themselves. In addition, in the competitive environment of enterprises, it is conducive to the rise of enterprise ability and indirectly affects the growth of corporate performance.

Research and development innovation is a persistent work, and this paper only discusses the short-term impact. In the past, many scholars have studied the situation that research and development have a deferential effect on the company's performance. When the deferential effect occurs, research and innovation may have different results on the biological vaccine industry.

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