Relationship between R&D Investment and Enterprise Performance of Pharmaceutical Enterprises in China: Research on 45 Domestic Listed Pharmaceutical Companies Based on Panel Data

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Abstract

Objective To study the causal relationship between R&D investment and enterprise performance of domestic pharmaceutical enterprises. **Methods** Panel data model was adopted for empirical analysis. **Results and Conclusion** Increasing the R&D investment intensity of pharmaceutical enterprises in the Yangtze River Delta and Zhejiang by 1% will increase their profit margins by 0.79% and 0.46%. On the contrary, if the profit margin increases by 1%, the R&D investment intensity will increase by 0.25% and 0.19%. If the profit margin of pharmaceutical enterprises in Beijing, Tianjin, Hebei, Chengdu, Chongqing and other regions increases by 1%, the R&D investment intensity will increase by 0.14%, 0.07% and 0.1%, respectively, which are lower than those in the Yangtze River Delta and Zhejiang. The relationship between R&D investment and enterprise performance of pharmaceutical enterprises in the Yangtze River Delta and Zhejiang Province is Granger causality, showing a two-way positive effect. Profits and R&D investment of pharmaceutical enterprises in Beijing, Tianjin, Hebei, Chengdu, Chongqing and other regions are also Granger causality. But in the Pearl River Delta, profits and R&D investment have not passed the stability test, it is impossible to determine the causality between them.

Keywords: R&D investment; enterprise performance; panel data model

1 Introduction

The 18th National Congress of the Communist Party of China proposed the implementation of the innovation driven development strategy. The 19th National Congress of the Communist Party of China further clarified that innovation is the primary driving force for development and the strategic support for building a modern economic system. To accelerate the construction of innovation abilities, local governments have successively introduced various incentive policies for drug research and development [1].

Since the new medical reform, especially after the implementation of volume-based procurement, Chinese government has issued a large number of policies to encourage pharmaceutical enterprises to increase innovation investment, such as measures for drug registration management, priority evaluation and approval systems. Innovative drugs will have a

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monopoly position and high prices during the patent period, which can earn more profits, thus encouraging domestic leading pharmaceutical companies to invest a large amount of funds in research and development innovation. The top domestic pharmaceutical companies are gradually forming a virtuous cycle of increasing research and development investment − new drug launch − increasing profits − increasing research and development investment, and thus growing into world-class pharmaceutical companies. In the process of new drug research and development, pharmaceutical companies can increase research and development investment to develop high threshold drugs. Once the new drug is marketed, it can achieve good market sales during the patent period and increase corporate profits. Besides, pharmaceutical companies can also increase R&D investment, improve the innovation environment for R&D personnel and innovative facilities, thereby improving R&D efficiency, shortening the time to market of new drugs, extending the market monopoly period, and increasing corporate profits.

2 Literature research

From current research, some scholars believe that there is a significant positive correlation between R&D investment and corporate performance [2-4]. However, other scholars have found that the impact of R&D investment on corporate performance is not significant, and even found that R&D investment may have a negative impact on corporate performance [5]. Liu Yun, et al. (2020) [6] found that the impact of current R&D expenditure on corporate performance was not significant. Zhang Jian et al. (2014) [7] found that the research and development activities of listed companies were negatively correlated with the performance of the companies in the year of research and development and the following two years, which had a more significant impact on the their profitability. Due to the long distance from R&D investment to production and marketing, R&D investment requires a large amount of funds, making it difficult to achieve profitability in the short term, which can affect the willingness of enterprises to invest in R&D, leading to a negative or unrelated relationship between R&D investment and enterprise growth [8, 9].

In terms of research methods, most scholars use the DEA-Malmquist index model for research. For example, Hashimoto A, et al. [10] selected the intensity indicators of R&D investment and three output indicators: Patent application number, main business income, and sales profit to study the R&D efficiency of 10 Japanese pharmaceutical companies over a 10-year period. Mahajan, et al. [11] selected four input indicators, namely raw material costs, employee salaries and bonuses, market advertising expenses, fixed assets, and net sales revenue, as output indicators to evaluate the R&D efficiency of 141 Indian pharmaceutical companies over the past 11 years. Their conclusion is that the R&D efficiency of pharmaceutical companies is not optimistic. Some scholars also use the panel data model for research. For example, Zhang Xuefen, et al. [12] used the panel data model to study the influencing factors of the technological innovation efficiency of the pharmaceutical manufacturing industry in 23 provinces of China, finding that R&D investment, new product demand and government support had a promoting effect on the technological innovation efficiency.

The reasons for the significant differences in the research conclusions of the above literature partially indicate that the relationship between enterprise R&D investment and enterprise performance is relatively complex. Differences in factors such as the nature of enterprise property rights, regional economic differences, enterprise sizes, and local government support policies can all affect the relationship between R&D investment and enterprise performance. This paper studied the top 100 pharmaceutical listed companies (top pharmaceutical companies) in China, and ultimately selected data from 45 pharmaceutical listed companies from 2014 to 2020 as the research object.

3 Data sources, variable settings, and model establishment

3.1 Data sources and variable settings

The relevant data of listed pharmaceutical companies were selected from the Pharmaceutical DataBase (PDB) from 2009 to 2020. The companies with incomplete data were eliminated after studying, and 45 companies were retained. The R&D intensity of a listed company is the proportion of R&D investment to operating revenue, indicating a company's strategic behavior and emphasis on R&D. Net profit margin is the proportion of net profit to operating revenue, representing a company's profitability and performance. The basic information of the data is shown in Table 1.

Table 1 Basic information of data

Year	R&D intensity			Profit margin		
	Average value	Number of cases	Standard deviation	Average value	Number of cases	Standard deviation
2009	0.039	28	0.029	0.202	38	0.173
2010	0.042	31	0.032	0.188	38	0.154
2011	0.045	35	0.032	0.181	38	0.175
2012	0.047	37	0.030	0.158	38	0.139
2013	0.056	38	0.046	0.153	38	0.140
2014	0.052	38	0.036	0.148	38	0.145
2015	0.067	38	0.078	0.149	38	0.141
2016	0.073	38	0.101	0.140	38	0.122
2017	0.064	38	0.046	0.143	38	0.122
2018	0.072	37	0.050	0.111	38	0.140
2019	0.059	36	0.053	0.014	38	0.305
2020	0.024	38	0.038	0.036	38	0.092
Total	0.054	432	0.054	0.135	456	0.169

In industrial organization, enterprise shareholders are the claimants of residual income after removing various input costs. Therefore, enterprise decision-makers often choose decisions that minimize costs and maximize profits [13]. In the context of national drug centralized procurement policies, it is difficult for domestic pharmaceutical companies to achieve large profit margin in their generic drug business [14]. Therefore, most leading pharmaceutical companies are gradually turning their profit points to innovative drugs, that is, increasing investment in the R&D of innovative drugs or first generic drugs, striving for a monopoly position in the future market, thus obtaining a higher profit level. Therefore, this article used these two data to study the R&D investment and performance of pharmaceutical companies, exploring the relationship between them, and providing theoretical support for future domestic pharmaceutical companies to choose appropriate R&D strategies.

3.2 Model establishment

Because panel data can not only establish econometric model by using cross-sectional data and time series data, but also better identify and measure the influencing factors that cannot be found in simple time series models and simple cross-sectional data models, it can construct and test more complex behavior models. Therefore, this paper used panel data model for empirical research.

4 Empirical analysis

4.1 Unit root test

Because panel data includes time dimension and section dimension data, when the time dimension is small, panel data can be used for direct modeling, but when the time dimension increases to a certain length, panel data needs to be tested for stability, that is, unit root test. The unit root of panel data can be divided into two types, one is the unit root test under the same root condition,, another is the unit root test under different root conditions, which allows for cross section changes. This article used two types of methods to test the data. The unit roots in the same root case are tested using the Levin-Lin-Chu (LLC) method, while the unit roots in different cases are tested using the augmented Dickey-Fuller (ADF) method. The test results are shown in Table 2, 3, and 4.

Table 2 Unit root test in the same root case

Area	Variable	Inspection form (C, T, K)	Inspection method	Statistic value	*P*	Conclusion
	LR			3.74	1.00	Non-stationary
	ΔLR			2.19	0.99	Non-stationary
	ΔΔLR			−2.35	0.01	Stationary
	YF			0.72	0.77	Non-stationary
	ΔYF			0.71	0.76	Non-stationary
Beijing, Tianjin, Hebei	ΔΔYF			−1.18	0.12	Stationary*
	LR			−1.20	0.12	Non-stationary
	ΔLR			5.21	1.00	Non-stationary
	ΔΔLR			0.45	0.68	Non-stationary
	YF			0.46	0.68	Non-stationary
	ΔYF			2.63	1.00	Non-stationary
Yangtze River Delta	ΔΔYF			0.49	0.69	Non-stationary
	LR			0.44	0.67	Non-stationary
	ΔLR			1.26	0.90	Non-stationary
	ΔΔLR			0.34	0.63	Non-stationary
Zhejiang	YF	(C, T, 1)	Levin-Lin-Chu *t*	−2.64	0.00	Stationary
	LR			−3.58	0.00	Stationary
	YF			−0.28	0.39	Non-stationary
Pearl River Delta	ΔYF			−4.33	0.00	Stationary
	LR			1.08	0.86	Non-stationary
	ΔLR			1.01	0.84	Non-stationary
	ΔΔLR			0.85	0.80	Non-stationary
	YF			−1.07	0.14	Non-stationary
	ΔYF			2.40	0.99	Non-stationary
Chengdu, Chongqing	ΔΔYF			1.22	0.89	Non-stationary
	LR			3.02	1.00	Non-stationary
	ΔLR			3.73	1.00	Non-stationary
	ΔΔLR			2.63	1.00	Non-stationary
	YF			2.85	1.00	Non-stationary
	ΔYF			2.54	0.99	Non-stationary
Other	ΔΔYF			−1.62	0.05	Stationary

Note: At the 12% significance level.

Table 3 Unit root test under different root cases

Area	Variable	Inspection form (C, T, K)	Inspection method	Statistical value	*P*	Conclusion
Beijing, Tianjin, Hebei	LR	(C, T, 1)	PP-Fisher Chi-square	40.60	0.00	Non-stationary
	YF			9.62	0.94	Stationary
Yangtze River Delta	LR			34.89	0.00	Stationary
	YF			20.91	0.10	Stationary*
	LR			20.03	0.33	Non-stationary
	ΔLR			61.68	0.00	Stationary
	YF			25.95	0.10	Stationary**
Zhejiang	YF			57.10	0.00	Stationary
	LR			13.59	0.09	Stationary
Pearl River Delta	YF			16.49	0.04	Stationary
	LR			2.18	0.98	Non-stationary
	ΔLR			7.89	0.44	Non-stationary
	ΔLR			28.94	0.00	Stationary
	YF			9.92	0.27	Non-stationary
Chengdu, Chongqing	ΔYF			16.50	0.04	Stationary
	LR			18.51	0.55	Non-stationary
	ΔLR			64.35	0.00	Stationary
	YF			13.26	0.87	Non-stationary
Other	ΔYF			30.48	0.06	Stationary

Note: *At the 10% significance level; **At the 12% significance level.

Table 4 Final results of unit root test

Area	Inspection method	Conclusion	Inspection method	Conclusion
Beijing, Tianjin, Hebei	Levin-Lin-Chu *t*	Stationary	PP-Fisher Chi-square	Non-stationary
Yangtze River Delta		Non-stationary		Stationary
Zhejiang		Non-stationary		Stationary
Pearl River Delta		Non-stationary		Stationary
Chengdu, Chongqing		Non-stationary		Non-stationary
Other		Non-stationary		Stationary

From Table 2, 3, and 4, it can be seen that the results of unit root test under different root conditions are as the followings. The data in Beijing, Tianjin, and Hebei are stationary after second-order difference, while the data in other regions are still unstable after second-order difference. Meanwhile, the results of unit root test under the same root situation areas the followings. The data in Beijing, Tianjin, Hebei, Chengdu and Chongqing still have non-stationary data after second-order difference, while the data in the Yangtze River Delta, Zhejiang, and other regions are stationary data after second-order difference at a 10% significance level. Besides, the data in the Pearl River Delta region is stationary data at a 10% significance level, and the data in Chengdu and Chongqing still have non-stationary data after second-order difference.

To sum up, at the 10% significance level, the data of Beijing, Tianjin, Hebei, Yangtze River Delta, Zhejiang, Pearl River Delta and other regions are stable after two differences at most. Therefore, a panel data model can be established by comprehensively considering the two test results.

4.2 Cointegration test

To verify whether there is a cointegration relationship between data from different regions, this article selected the Kao test method for cointegration testing, and the specific data is shown in Table 5.

Table 5 Cointegration test of panel data model

Area	Inspection method	*t*-statistic	Prob.
Beijing, Tianjin, Hebei	ADF	−1.64	0.05
Yangtze River Delta		−2.36	0.01
Zhejiang		−3.13	0.00
Pearl River Delta		−0.27	0.39
Chengdu, Chongqing		−1.81	0.04
Others		−4.02	0.00

From Table 5, it can be seen that except for the Pearl River Delta region, the *P*-values of the *t*-test in all other regions are less than 0.05. Therefore, the original hypothesis can be rejected, and there is a cointegration relationship between the data from Beijing, Tianjin, Hebei, Yangtze River Delta, Zhejiang, Chengdu, Chongqing, and other regions.

4.3 Granger causality test

Granger causality test was initiated by Clive WJ Granger, the winner of the Nobel Prize in Economics in 2003, to analyze the Granger causality between economic variables. He defined Granger causality as the variance that relies on the best least squares prediction of all information at certain time points in the past. To test the causal relationship between profit and R&D investment, that is, whether profit promotes an increase in R&D investment or whether R&D investment increases the company's profit. This article conducted a Granger causality test on various regional models, and the test results are shown in Table 6.

Table 6 Granger causality test

Area	Null hypothesis	Obs	*F*-statistic	Prob.
Beijing, Tianjin, Hebei	LR does not Granger Cause YF	79	2.96	0.06
	YF does not Granger Cause LR		0.26	0.77
Yangtze River Delta	LR does not Granger Cause YF	67	5.01	0.01
	YF does not Granger Cause LR		5.19	0.01
Zhejiang	LR does not Granger Cause YF	88	4.95	0.01
	YF does not Granger Cause LR		3.57	0.03
Chengdu, Chongqing	LR does not Granger Cause YF	40	2.38	0.11
	YF does not Granger Cause LR		1.20	1.14
Others	LR does not Granger Cause YF	86	4.79	0.01
	YF does not Granger Cause LR		1.58	0.21

From Table 6, it can be seen that all models reject the assumption that profit is not a Granger causality of R&D investment, and it can be concluded that profit is a Granger causality of R&D investment. Meanwhile, the Yangtze River Delta and Zhejiang have rejected the assumption that R&D investment is not a Granger causality of profit, and it can be concluded that R&D investment is also a Granger causality of profit. Therefore, seven models can be established, namely five cointegration regression models with R&D investment as the dependent variable and profit as the independent variable, and two cointegration regression models with profit as the dependent variable and R&D investment as the independent variable.

4.4 Empirical results of panel data

Due to the unified influence of the policies of central government on the pharmaceutical industry of various provinces and cities in China, there may be some contemporaneous correlation between variables. Therefore, this article added a seemingly unrelated regression model for estimation to improve the measurement results. The specific measurement results are shown in Table 7.

Table 7 Measurement results of panel data model

Area	Variable	Parameter	*t*	*P*	Adjusted R^2	*D-W*	*P* (*F*)
Beijing, Tianjin, Hebei	C	0.02	10.81	0			
	LR	0.14	18.48	0	0.81	1.59	0
Yangtze River Delta	C	0.02	8.23	0			
	LR	0.25	12.67	0	0.69	1.39	0
	C	0.07	14.00	0			
	YF	0.79	7.00	0	0.39	1.45	0
Zhejiang	C	0.04	43.23	0			
	LR	0.19	30.41	0	0.90	1.75	0
	C	0.08	22.76	0			
	YF	0.46	5.98	0	0.26	1.55	0
Chengdu, Chongqing	C	0.06	13.79	0			
	LR	0.07	2.32	0.03	0.08	1.27	0.03
Other	C	0.03	24.40	0			
	LR	0.10	10.77	0	0.58	1.38	0

From the measurement results in Table 7, it can be seen that the *P*-values of each variable parameter are all less than 0.05. Through significance testing, except for the models with independent variables of R&D investment in Chengdu, Chongqing, Zhejiang, and the Yangtze River Delta, the adjusted goodness of fit is 0.08, 0.26, and 0.39, which are smaller. All other models are above 0.5, indicating that fitting effect of the model is good.

5 Conclusion and recommendations

5.1 Conclusion

(1) A bidirectional positive effect between the R&D investment intensity and corporate performance of listed pharmaceutical companies in the Yangtze River Delta and Zhejiang province.

From the data in Table 7, it can be seen that there is a bidirectional positive effect between the R&D investment intensity and corporate performance of listed pharmaceutical companies in the Yangtze River Delta and Zhejiang province, that is, there is a Granger causality relationship between R&D investment and corporate performance. Therefore, increasing the intensity of R&D investment is beneficial for improving the profit level of enterprises, and in turn, increasing the profit level of enterprises can also increase the intensity of R&D investment. From the adjusted goodness of fit, the profit margin variables in the two regions have a better promotion effect on R&D investment, with values of 0.69 and 0.90, respectively, indicating that the profit margin variables can better explain the R&D investment variables. On the contrary, the variable of R&D investment intensity in the two regions has a relatively weaker effect on improving corporate performance, with values of 0.39 and 0.26, respectively. This indicates that the explanatory power of R&D investment on profit margin variables in the two regions is weak. This conclusion is also easy to understand because there are more factors that affect profit margins, not only due to the R&D investment intensity, but also factors such as market competition, sales ability, and cost control that constrain the size of profit margins.

(2) A better explanation between the profit margin variables and R&D investment in Beijing, Tianjin, Hebei and other regions.

From the adjusted goodness of fit, Beijing, Tianjin, Hebei and other regions are 0.81 and 0.58 respectively, which is relatively high, indicating that the profit rate variables can better explain the R&D investment intensity. For innovative pharmaceutical companies, a higher profit margin means that there is sufficient funds for new drug research and development. On the other hand, in the capital market, it can also attract more social capital to invest in new drug research and development, especially in Beijing. Tianjin, and Hebei province, where innovative resources and financing channels are relatively better. Therefore, as the profit margin increases, more investment will be made in product research and development.

(3) Insignificant causal relationship between the Pearl River Delta and Chengdu and Chongqing.

Table 4 shows that there is no cointegration relationship between R&D investment intensity and profit margin variables of listed pharmaceutical enterprises in the Pearl River Delta. Although there is a cointegration relationship between the two in Chengdu and Chongqing, the goodness of fit is only 0.08, and the profit margin variables can hardly explain the change of R&D investment intensity variables. One reason for this result may be that there is less data, which means there are fewer companies included in the model, or the time series included in the model is shorter. The second is that listed pharmaceutical companies in these regions are undergoing transformation and upgrading, and the conversion of R&D investment into profit margins or profits has not yet been made into effective R&D investment, resulting in a lack of causal relationship between the two.

5.2 Recommendations

Under the national drug centralized procurement policy, relying on the cluster model of generic pharmaceutical products to expand the market is no longer in line with the trend of the times. The decision maker of pharmaceutical companies should establish a closed-loop strategy of enterprise profit (income) − R&D investment − high profit − high R&D investment. In the future, it is urgent for domestic pharmaceutical companies to choose a path of transformation and upgrading that is suitable for them. Pharmaceutical enterprises in the Yangtze River Delta and Zhejiang province have taken the lead in exploring and demonstrating, such as Zhejiang Haizheng, Zhejiang Huahai, Xianju, Kyushu, Aoxiang, and other pharmaceutical enterprises. Zhejiang Haizheng and Zhejiang Huahai have gradually expanded into the pharmaceutical field by relying on the export of high-end raw material drug markets, and they have achieved successful transformation. Xianju Pharmaceutical has achieved a transformation from raw materials to the integration of raw materials and preparations, while Kyushu Pharmaceutical and Aoxiang Pharmaceutical have achieved transformation and upgrading to Contract Development Manufacture Organization (CDMO) enterprises. From the successful transformation and upgrading paths of these listed pharmaceutical companies in Zhejiang, we can find out several transformation paths for current domestic pharmaceutical companies. The first is they have the production capacity of characteristic raw materials, then they can transform and upgrade into CDMO enterprises, and finally become innovative drug research and development and production enterprises. The second is for enterprises with bulk raw material drug production to achieve the integration of raw materials and preparations, and obtain economies of scale through the first and high-end generic drug strategies. At present, the government encourages the first generic drug system, and the threshold for high-end generic drugs is high, which will lessen certain market competition to ensure that enterprises can obtain certain profits for later research and development.

In this sense, these pharmaceutical enterprises in Zhejiang have achieved a virtuous cycle of causality between R&D investment and profits. Local governments in other regions should learn from some the experience in Zhejiang Province to encourage innovative development of pharmaceutical enterprises. Otherwise, in the future, domestic pharmaceutical enterprises will also gather in areas that are conducive to the development of innovative drugs.

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