Research on the Relationship between Government R&D Subsidies of Different Sub-industries in China's Pharmaceutical Industry and Enterprises' R&D Investment

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Abstract

Objective To empirically analyze the relationship between Government R&D funding and R&D investment of the enterprises in different sub industries of pharmaceutical industry, and to provide reference for the development of policies related to R&D funding input. **Methods** Granger causality test was performed using the data of relevant indicators in different sub industries of China's pharmaceutical industry from 1995 to 2019 based on the theory of covariance. **Results and Conclusion** The funding of R&D from the government had a significant positive effect on their R&D funding inputs to enterprises with chemo products, Chinese patent products, and biological products. It means the improvement of government funding was beneficial in promoting the R&D investment from various sub industries of pharmaceutical industry. The order of this influence was biological products, chemo products, and Chinese patent drugs. As to chemical drugs and biological products, the government's R&D funding and enterprises R&D funding input showed a good trend of mutual promotion in a certain lag period. The government can fully leverage its funding to promote the investment of all sub industries of pharmaceutical industry. Meanwhile, regulatory mechanisms should be refined for government funding. For the inheritance, innovation, and development of traditional Chinese medicine, the government should give more policy support than financial support.

Keywords: pharmaceutical industry; government R&D subsidies; enterprise's R&D investment; cointegration theory

As one of the high-tech industries, pharmaceutical industry can greatly promote the growth of China's national economy. As early as 1995, The State Council of China put forward the strategic slogan of giving priority to the development of high-tech industry. Since then, a series of policies and measures have been introduced to support and promote the development of high-tech industry. In the 19th National Congress of the Communist Party of China, it clearly put forward that "innovation is the first driving force for development and the strategic support for building a modernized economic system". Therefore, Chinese government has increased more subsidies to enterprises to better promote the level of high-tech industry innovation. Pharmaceutical industry is one of the important

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subsidized industries. According to the "Statistical Yearbook of China High Technology Industry" [1], from 1995 to 2019, the government's R&D expenditure in pharmaceutical industry increased from 270 million yuan to 29.2 billion yuan, more than a hundred times in 25 years. Whether the R&D subsidies from the government have effectively achieved the initial goal, or whether the government's R&D subsidies have effectively driven the R&D investment of pharmaceutical enterprises? For the above questions, we cannot get an answer from the past research. Therefore, this paper takes different sub-industries of pharmaceutical industry as the research object, and empirically analyzes the relationship between government R&D subsidies and enterprises' R&D input, aiming at providing theoretical and practical reference for the formulation of relevant policies by the government.

1 Theoretical analysis

Many scholars have paid attention to the research on the relationship between government R&D subsidies and enterprises' R&D investment for a long time, but no consensus has been reached on the conclusions, which mainly include leverage effect, crowding out effect and curve effect.

1.1 Leverage effect on enterprises' R&D investment from government R&D subsidies

Leverage effect is the positive incentive effect. Based on the data of German enterprises, Birgit (2009) [2] concluded that government funding can significantly promote enterprise innovation input. Zhang Donghong, et al. (2009) [3] found through their research that government R&D subsidies and enterprises' R&D efficiency could complement each other and promote enterprises' profit margins for an increase of R&D input. Chen Ling, et al. (2016) [4] found that different government R&D subsidies had a significant positive incentive effect on enterprises' independent R&D input. Some scholars used inter-provincial panel data of large and medium-sized industrial enterprises for research. For instance, Liao Xinlin, et al. (2013) [5] studied the relationship between government R&D subsidies and enterprise innovation investment and found that there was a leverage effect, and the development in the industrialization stage would promote enterprise R&D investment. Wei Fang and Geng Xiulin (2018) [6], based on the research of listed companies on Chinext, found that government funding was undoubtedly conducive to their innovation activities, and enterprise funding was one of the important means for government to encourage enterprise innovation. Liu Yuhong (2020) [7], in his study on the impact of R&D subsidies of listed manufacturing companies in China on enterprise technological innovation, also found that R&D subsidies significantly stimulated enterprise R&D input and innovation output.

1.2 Crowding out effect on enterprises' R&D investment from government R&D subsidies

The crowding out effect has a negative effect. Lu Jiuqin, et al. (2011) [8], found that government funding had a significant crowding out effect on enterprise technological innovation when they studied the impact of government funding on enterprise technological innovation. Taking high-tech enterprises in Guangdong Province as the research object, Zhou Haitao and Zhang Zhengang (2015) [9] found that direct government subsidies were more likely to produce crowding out effect on R&D input of enterprises. Li Yong, et al. (2015) [10] studied the inter-provincial panel data of large and medium-sized industrial enterprises and found that government R&D subsidies had a crowding out effect on enterprises' R&D input due to institutional constraints. Zhang Jie, et al. (2021) [11] found in their research that the optimal level of innovation input of some enterprises had been determined by the state of market competition, and the subsidy funds given by the government would not further stimulate the innovation input of enterprises, but it would only form substitution effect and crowding out effect on their innovation input.

1.3 Curve effect on enterprise R&D investment from government R&D subsidies

Mao Qilin, et al. (2015) [12] found in their research that excessive government funding would inhibit enterprises' innovation of new products, and there was an inverted U-shaped relationship between the intensity of government funding and enterprises' input. Zhang Caijiang, et al. (2016) [13], who took the data of innovative listed enterprises in the Pearl River Delta as samples, and Li Yuanyuan, et al. (2019) [14], who took heavily polluting enterprises among China's A-share listed companies as samples, found that there was a significant inverted U-shaped relationship between government funding and enterprise technological innovation. In their study on the performance of government subsidies in China's pharmaceutical industry, Shang Hongtao and Huang Xiaoshuo (2019) [15] found that government subsidies had a significantly positive U-shaped relationship with innovation output in specific periods among enterprises of different natures and sizes. An Chenyu, et al. (2018) [16] conducted an empirical study on the inter-provincial panel data of China's pharmaceutical industry and found that government funding had a significant threshold effect on enterprises' R&D input, which generally presented an inverted U-shape.

After sorting out and summarizing the existing studies, we find that although there are many literatures on the relationship between government R&D subsidies and enterprise R&D investment, few studies take pharmaceutical industry as the research object and make comparison between different sub-industries. Therefore, this paper draws on the previous research experience, takes different sub-industries of pharmaceutical industry as the research object, and empirically analyzes the relationship between the government R&D subsidies and enterprises' R&D investment in the internal R&D expenditure of chemical drugs, traditional patent medicine and biological products, thus getting more targeted conclusions.

2 Research design

2.1 Research method

Although the two variables have their own laws of time fluctuation, if they conform to the homogeneity of the same order, there may be a long-term stable proportional relationship between them, which is called co-integration relationship [17]. In the economic data, most of the variables are non-stationary behaviors, which tend to rise or fall with the change of time. If the regression analysis of non-stationary time series variables is conducted directly, the problem of false regression will occur, and the cointegration analysis can avoid the problem of false regression well.

This paper uses co-integration analysis and Granger causality test to analyze the relationship between government R&D subsidies of different sub-industries and enterprises' R&D input.

2.2 Data sources and index selection

In this paper, according to the classification of different sub-industries in the "Statistical Yearbook of China's High-Tech Industry", pharmaceutical industry is divided into chemical drugs, Chinese patent drugs and biological products. From the perspective of different sub-industries of pharmaceutical industry, the relationship between the government R&D subsidies and the R&D investment of pharmaceutical enterprises is analyzed empirically. Considering the availability of data, this paper selects relevant index data from 1995 to 2019 for empirical research, all of which are from the "Statistical Yearbook of China High Technology Industry".

The explanatory variables of this paper are government R&D subsidies, which are measured by government funds in R&D internal expenditure (GF). The explained variable of this paper is the R&D expenditure of pharmaceutical industry, which is measured by the enterprise funds (EF) in the R&D internal expenditure of pharmaceutical industry. The specific data is shown in Table 1, and the related indicators are shown in Table 2.

Table 1 Amount of government funds (GF) and enterprise funds (EF) in each sub-industry of pharmaceutical industry from 1995 to 2019 (Unit: Ten thousand yuan)

Year	Government funds (GF)			Enterprise funds (EF)		
	Chemical drug	Chinese patent medicine	Biological product	Chemical drug	Chinese patent medicine	Biological product
1995	1 374	221	704	59 957	13 205	3 315
1996	5 804	949	187	60 456	17 022	4 428
1997	6 774	1 209	1 178	77 896	16 530	15 640
1998	5 263	1 312	116	110 625	31 904	7 877
1999	6 046	1 631	3 096	111 768	52 488	13 051
2000	7 263	3 235	1 318	205 632	79 982	25 959
2001	5 992	4 038	1 381	232 547	91 377	33 193
2002	13 154	4 532	2 135	297 405	120 862	31 640
2003	9 755	5 448	1 158	349 539	118 288	31 110
2004	19 720	11 708	2 088	411 447	143 817	26 708
2005	17 216	10 436	4 789	506 446	167 144	35 602
2006	21 644	10 650	4 418	570 833	247 050	47 871
2007	27 454	17 758	7 127	712 023	310 029	79 518
2008	36 415	21 764	7 572	772 933	277 979	104 332
2009	38 947	22 780	14 551	714 656	244 559	163 104
2010	51 276	16 824	16 840	741 527	186 998	114 571
2011	68 693	27 218	17 322	1 140 824	355 023	271 967
2012	88 506	47 498	27 632	1 425 554	506 048	414 812
2013	85 574	52 598	40 652	1 749 003	660 198	487 818
2014	83 631	50 240	45 237	1 948 840	719 271	603 676
2015	92 028	48 346	46 997	2 215 267	756 543	690 363
2016	104 572	55 300	45 004	2 399 303	866 563	778 373
2017	103 489	53 492	44 744	2 779 682	845 434	838 705
2018	102 405	51 683	44 483	3 160 061	824 305	899 038
2019	179 943	38 151	44 480	3 083 131	872 966	1 182 392

Table 2 Indicators selected in this study and their descriptions

Variable name	Measure index	Symbolic representation	Indicator description
Government R&D subsidy	Government funds	Chemical drug (H-GF) Traditional patent medicine (Z-GF) Biological products (S-GF)	Internal expenditure of R&D funds from various levels of government departments
Pharmaceutical manufacturing industry's own R&D investment	Enterprise funds	Chemical drug (H-EF) Traditional patent medicine (Z-EF) Biological products (S-EF)	The internal R&D expenditure of the research unit comes from the enterprise's own funds and the funds obtained from the commission of other enterprises

3 Empirical analysis

3.1 Unit root test

Before conducting the co-integration test of variables, the stationarity test of time series variables is needed to determine whether the integration test is full. In this paper, logarithm of the original data was selected and augmented dickey fuller (ADF) method was used to conduct unit root test for each variable. The optimal lag order of unit root was determined according to Akaike information criterion (AIC). The results of ADF unit root test are shown in Table 3.

Table 3 Results of unit root test

Variable	Check type (C, T, K)	ADF	Critical values for each significance level			*P* value	Result
			1%	5%	10%		
ln*H-GF*	(C, T, 1)	−2.402 225	−4.416 3	−3.622 0	−3.248 5	0.368 7	Nonstationary
ln*H-EF*	(C, T, 0)	−1.533 588	−4.394 3	−3.612 1	−3.243 0	0.788 7	Nonstationary
Δln*H-GF*	(C, 0, 0)	−8.921 223	−3.752 9	−2.998 0	−2.638 7	0.000 0	Steady
Δln*H-EF*	(C, 0, 0)	−5.370 021	−3.752 9	−2.998 0	−2.638 7	0.000 2	Steady
ln*Z-GF*	(C, T, 0)	−2.738 132	−4.394 3	−3.612 1	−3.243 0	0.231 4	Nonstationary
ln*Z-EF*	(C, T, 0)	−2.158 353	−4.416 3	−3.622 0	−3.248 5	0.488 7	Nonstationary
Δln*Z-GF*	(C, 0, 0)	−5.707 323	−3.752 9	−2.998 0	−2.638 7	0.000 1	Steady
Δln*Z-EF*	(C, 0, 0)	−3.700 433	−3.752 9	−2.998 0	−2.638 7	0.011 2	Steady
ln*S-GF*	(C, T, 0)	−6.728 644	−4.394 3	−3.612 1	−3.243 0	0.000 1	Steady
ln*S-EF*	(C, T, 0)	−3.510 640	−4.394 3	−3.612 1	−3.243 0	0.060 8	Nonstationary
Δ ln*S-GF*	(C, 0, 0)	−13.730 300	−3.752 9	−2.998 0	−2.638 7	0.000 0	Steady
Δ ln*S-EF*	(C, 0, 0)	−6.508 348	−3.752 9	−2.998 0	−2.638 7	0.000 0	Steady

Note: Δ represents first-order difference; In the test form (C, T, K), C, T and K respectively represent the constant term, time trend term and lag order included in the unit root test. 0 means that the test equation does not include the constant term or the time trend term or the lag order is 0.

As can be seen from Table 3, the original sequences of ln*H-GF*, ln*H-EF*, ln*Z-GF*, ln*Z-EF*, and ln*S-EF* all have unit roots at 1% and 5% confidence levels, indicating that their original sequences are non-stationary time series. First order difference is performed on the original sequence of all-time series variables, and then the ADF unit root test is carried out. The results show that the absolute values of ADF statistics of the series Δ ln*H-GF*, Δ ln*H-EF*, Δ ln*Z-GF*, Δ ln*Z-EF*, Δ ln*S-GF*, and Δ ln*S-EF* are all larger than the critical value at the 5% or 1% confidence level, indicating that they reject the null hypothesis of the existence of unit root and are all stationary time series. And all of them are of first order. Although the selected horizontal sequence is non-stationary or non-homo integration, as long as the first-order difference sequence is homo integration, it can be considered that the linear combination between the two pairs may be stable and meet the conditions of co-integration test.

3.2 Cointegration test

In this study, E-G two-step method was used for data co-integration test to analyze whether there is a long-term equilibrium relationship between government R&D subsidies and enterprises' R&D investment in different sub-industries of Chinese pharmaceutical industry. First, OLS regression was performed on ln*H-GF* and ln*H-EF*, ln*Z-GF* and ln*Z-EF*, and ln*S-GF* and ln*S-EF*. Finally, regression equations between chemical drugs, Chinese patent

drugs and biological products were obtained respectively.

(1) Chemical drugs:

$\ln H\text{-}EF = 0.928\ 34 \ln H\text{-}GF + 3.638\ 004$;

$R^2 = 0.928\ 340$, $F = 297.961\ 5$;

(2) Chinese patent medicine:

$\ln Z\text{-}EF = 0.823\ 805 \ln Z\text{-}GF + 4.504\ 959$;

$R^2 = 0.952\ 032$, $F = 456.482\ 8$;

(3) Biological products:

$\ln S\text{-}EF = 0.936\ 414 \ln S\text{-}GF + 3.220\ 918$;

$R^2 = 0.898\ 898$, $F = 204.493\ 8$.

As can be seen from the above regression results, R^2 of the three regression equations is close to 1, and F value of the three equations is large, indicating a good degree of equation fitting. Then, unit root test was conducted for residual terms of $e_{\ln H}$, $e_{\ln Z}$ and $e_{\ln S}$ squares obtained by the three regression equations, and the test results are shown in Table 4.

Table 4 Unit root test results of residual items

Variable	Check type	ADF	*P* value	Result
$e_{\ln H}$	(C, 0, 0)	−3.931 043	0.000 4	Steady
$e_{\ln Z}$	(C, 0, 0)	−3.385 346	0.001 6	Steady
$e_{\ln S}$	(C, 0, 0)	−6.379 394	0.000 0	Steady

As can be seen from Table 4, the residual terms of the three regression equations all reject the null hypothesis of the existence of unit roots at the 1% confidence level and are stationary time series, which further indicates that ln *H-GF* and ln*H-EF*, ln*Z-GF* and ln*Z-EF*, and ln*S-GF* and ln*S-EF* all pass the test of co-integration relationship. There is a long-term stable co-integration relationship.

Therefore, according to the above three co-integration equations, the elastic coefficients between government R&D subsidies for chemical drugs, Chinese patent drugs and biological products and enterprises' R&D investment are 0.928 340, 0.823 805 and 0.936 414, respectively. It means every 1% increase of ln*H-GF* will cause an increase of 0.928 340% of ln*H-EF*. If ln*Z-GF* increases by 1%, ln*Z-EF* will change in the same direction by 0.823 805%. When the ln*S-GF* changes by 1%, the ln*S-EF* will change in the same direction by 0.936 414%.

This indicates that the government R&D subsidies of different sub-industries of pharmaceutical industry have a positive promoting effect on the R&D investment of enterprises, and this promoting effect is in the order of biological products, chemical drugs and Chinese patent drugs from the largest to the smallest.

After the co-integration test of variables is conducted, we find there is a long-term stable co-integration relationship between variables. Then, an error correction model can be established to test whether the reverse error correction mechanism is set up and the short-term influence between variables can be obtained. As the error correction terms $ecm_{\ln H} = e_{\ln H}$, $ecm_{\ln Z} = e_{\ln Z}$, $ecm_{\ln S} = e_{\ln S}$, the results after establishing the error correction model show that the coefficients of the three error correction terms are −0.234 800, −0.381 294 and −0.541 120, respectively. This indicates that when the short-term fluctuation between variables deviates from the long-term equilibrium state, the intensity of 0.234 800, 0.381 294 and 0.541 120 will correct the disequilibrium state of the previous period back to the equilibrium state respectively. In addition, the coefficients of error correction items in the three models are all less than 0, indicating that the reverse error correction mechanism is established.

3.3 Model parameter estimation

3.3.1 Chemical drugs

The lag period is set as 5, and Granger causality test is carried out on the government R&D subsidies and enterprises' R&D funding investment in pharmaceutical industry lagging 1−5 periods, and the results are shown in Table 5.

Table 5 Granger causality test results of ln*H-GF* and ln*H-EF* in chemical drugs

Lag period	Null hypothesis	*F* statistic	*P* value	Result
1	ln*H-GF* is not the Granger cause of ln*H-EF*	4.823 11	0.039 5	Reject null hypothesis
	ln*H-EF* is not the Granger cause of ln*H-GF*	10.655 00	0.003 7	Reject null hypothesis
2	ln*H-GF* is not the Granger cause of ln*H-EF*	0.843 54	0.446 5	Accept the null hypothesis
	ln*H-EF* is not the Granger cause of ln*H-GF*	4.213 86	0.031 5	Reject null hypothesis
3	ln*H-GF* is not the Granger cause of ln*H-EF*	1.004 10	0.418 1	Accept the null hypothesis
	ln*H-EF* is not the Granger cause of ln*H-GF*	1.870 37	0.178 0	Accept the null hypothesis
4	ln*H-GF* is not the Granger cause of ln*H-EF*	3.026 78	0.061 1	Reject null hypothesis
	ln*H-EF* is not the Granger cause of ln*H-GF*	3.751 38	0.033 4	Reject null hypothesis
5	ln*H-GF* is not the Granger cause of ln*H-EF*	1.714 35	0.227 1	Accept the null hypothesis
	ln*H-EF* is not the Granger cause of ln*H-GF*	1.860 55	0.197 1	Accept the null hypothesis

As can be seen from Table 5, ln*H-EF* and ln*H-GF* can be considered as Granger causes of each other at the confidence level of 5% or 10% when the lag period 1 and 4 is delayed. When the confidence level is 5%, ln*H-EF* is considered to be the Granger cause of ln*H-GF*, but vice versa is not true, indicating that the R&D investment of pharmaceutical enterprises can significantly explain or predict the amount of government R&D subsidies to enterprises, while vice versa is not true. The null hypothesis is accepted when the lag period is 3 and 5, that is, there is no Granger causality between ln*H-GF* and ln *H-EF*.

3.3.2 Traditional patent medicine

The lag period is set as 5, and Granger causality test is conducted on the government R&D subsidies and enterprises' R&D funding investment in the Chinese patent medicine industry with a lag period of 1−5, and the results were shown in Table 6.

Table 6 Causality test results of ln*Z-GF* and ln*Z-EF* Granger in Chinese patent medicine industry

Lag period	Null hypothesis	*F* statistic	*P* value	Result
1	ln*Z-GF* is not the Granger cause of ln*Z-EF*	0.509 81	0.483 1	Accept the null hypothesis
	ln*Z-EF* is not the Granger cause of ln*Z-GF*	6.572 12	0.018 1	Reject null hypothesis
2	ln*Z-GF* is not the Granger cause of ln*Z-EF*	7.537 77	0.004 2	Reject the null hypothesis
	ln*Z-EF* is not the Granger cause of ln*Z-GF*	1.262 22	0.306 9	Accept the null hypothesis
3	ln*Z-GF* is not the Granger cause of ln*Z-EF*	2.638 41	0.087 5	Reject the null hypothesis
	ln*Z-EF* is not the Granger cause of ln*Z-GF*	1.459 19	0.265 5	Accept the null hypothesis
4	ln*Z-GF* is not the Granger cause of ln*Z-EF*	2.084 91	0.145 9	Accept the null hypothesis
	ln*Z-EF* is not the Granger cause of ln*Z-GF*	1.284 70	0.329 8	Accept the null hypothesis
5	ln*Z-GF* is not the Granger cause of ln*Z-EF*	1.225 84	0.371 7	Accept the null hypothesis
	ln*Z-EF* is not the Granger cause of ln*Z-GF*	0.804 08	0.574 2	Accept the null hypothesis

As can be seen from Table 6, ln*Z-EF* is considered to be the Granger cause of ln*Z-GF* at the confidence level of 5% when the lag is one stage. Otherwise, it is not true, indicating that the amount of R&D funds invested by enterprises can significantly explain or predict the amount of government R&D

subsidies for traditional Chinese medicine industry. Otherwise, it is not true. At the second and third stage, ln*Z-GF* is considered to be the Granger cause of ln*Z-EF* at the confidence level of 1% and 10%, respectively, indicating that the amount of government subsidies to the TCM industry can significantly explain or predict the amount of R&D investment of enterprises. At the 4th and 5th stages, the null hypothesis is accepted, that is, there is no Granger causality between ln*Z-GF* and ln*Z-EF*.

3.3.3 Biological products

The lag period is set as 5, and the Granger causality test is conducted on the government R&D subsidies and the enterprise's R&D expenditure in the biological products industry with a lag of 1−5 periods. The results are shown in Table 7.

Table 7 Results of causality test between ln*S-GF* and ln*S-EF* Granger in biological products industry

Lag period	Null hypothesis	*F* statistic	*P* value	Result
1	ln*S-GF* is not the Granger cause of ln*S-EF*	0.156 17	0.696 7	Accept the null hypothesis
	ln*S-EF* is not the Granger cause of ln*S-GF*	15.389 80	0.000 8	Reject the null hypothesis
2	ln*S-GF* is not the Granger cause of ln*S-EF*	5.542 51	0.013 3	Reject the null hypothesis
	ln*S-EF* is not the Granger cause of ln*S-GF*	2.794 19	0.087 7	Reject the null hypothesis
3	ln*S-GF* is not the Granger cause of ln*S-EF*	2.619 19	0.089 0	Reject the null hypothesis
	ln*S-EF* is not the Granger cause of ln*S-GF*	1.607 09	0.229 6	Accept the null hypothesis
4	ln*S-GF* is not the Granger cause of ln*S-EF*	1.112 76	0.395 3	Accept the null hypothesis
	ln*S-EF* is not the Granger cause of ln*S-GF*	0.418 97	0.792 0	Accept the null hypothesis
5	ln*S-GF* is not the Granger cause of ln*S-EF*	1.614 20	0.250 7	Accept the null hypothesis
	ln*S-EF* is not the Granger cause of ln*S-GF*	2.112 63	0.155 5	Accept the null hypothesis

As can be seen from Table 7, at the confidence level of 1%, ln*S-EF* is considered to be the Granger cause of ln*S-GF*, but vice versa is not true, indicating that the enterprise's R&D funding can significantly explain or predict the government R&D funding for biological products industry, while vice versa is not true. In the second lag stage, the Granger causes of the two are considered to be mutual under the confidence level of 5% and 10% respectively. In the third lag stage, it indicates that the amount of government subsidies to the biological products industry can significantly explain or predict the amount of R&D investment of enterprises. In the 4th and 5th stages, the null hypothesis is accepted, that is, there is no Granger causality between ln*S-GF* and ln*S-EF*.

4 Conclusion

For Chinese pharmaceutical industry, government R&D subsidies can reduce their R&D cost and risk of enterprises, . Then, enterprises can continue the project due to the support of innovation funds from the government. Due to the influence of the "market failure", enterprises' enthusiasm for innovation is reduced, but the government's R&D funding inhibits the negative impact of "market failure" to a certain extent [18]. These factors enable the government R&D subsidies to have an incentive effect on the R&D investment of each sub-industry in the pharmaceutical industry, namely leverage effect.

4.1 Chemical drugs

The empirical research results show that when the government funds of chemical and pharmaceutical industry increase by 1%, the corresponding R&D expenditure of enterprises will increase by 0.928 340%. It means that there is a long-term and stable equilibrium between government funding in pharmaceutical industry and the intensity of corporate

funding input, which has a positive promoting effect on the R&D funding input of enterprises in the chemical drug industry. From the Granger causality test results, lagging periods 1 and 4, the government funds in the chemical drug industry have mutually Granger reasons in lag period 1 and 4. In lag period 2, the input from enterprises' funds is Granger's reason for government funding input. Due to the large size of the chemical drug industry with maturation, it is significant for government subsidies to affect the results, which also increase the willingness of government to invest more.

4.2 Chinese patent medicine

For every 1% increase in government funds in the Chinese patent industry, its corresponding enterprise's R&D investment will increase by 0.823 805%. From the perspective of elasticity coefficient, the incentive effect of the increase of government funds on the increase of enterprise's funds in the Chinese patent medicine industry is weaker than that of chemical medicine and biological products sub-industry. The reason may be that the particularity of Chinese patent medicine is different from chemical drugs and biological products. Chinese patent medicine enterprises are currently facing many challenges in development and listing. First of all, the clinical effect of its products needs to be scientifically verified. Meanwhile, there are hidden dangers in the safety of individual varieties. In addition, the lack of follow-up drug development is also a problem [19]. These problems will increase the uncertainty of input and output in the Chinese patent medicine industry, resulting in a slightly lower investment willingness of enterprises.

4.3 Biological products

For every 1% increase of government funds in the internal R&D expenditure of biological products sub-industries, the corresponding enterprises' R&D expenditure will increase by 0.936 414%. It shows that there is a long-term stable equilibrium relationship between the two. From the perspective of Granger causality, the two are also Granger causality of each other when the lag period is 3. From the perspective of elasticity coefficient, the positive influence of biological products on government funds is the most significant among the three sub-industries of pharmaceutical industry. This favorable trend is inseparable from the fact that in recent years, the biological drug industry in China has received high attention from governments at all levels with the key support of national industrial policies. The government has introduced a number of policies to encourage the development and innovation of the biological medicine industry. Many industrial policies have provided a clear and broad market prospect for the development of the biological medicine industry.

5 Suggestions

Firstly, we should give full play to the leverage effect of government funds. Therefore, the government can continue to increase the financial support to the sub-industries of pharmaceutical industry. Then, within the scope of governmental financial resources at all levels, the R&D subsidies of various industries of Chinese pharmaceutical enterprises can be appropriately increased to promote the leverage effect of government funds. As to chemical drugs and biological products, the R&D subsidies of the government and the enterprises' R&D investment show a good trend of mutual promotion in a certain lag period.

Second, the supervision mechanism of government funds should be improved. When selecting subsidized enterprises, emphasis should be placed on the innovation qualification of enterprises, and the funds should be granted to innovative enterprises with good strength and development potential [20].

Thirdly, for the transmission innovation and development of Chinese patent medicines, government should also pay more attention to policy support except for funding. Compared with chemical drugs and biological products, Chinese patent innovation is more difficult to achieve, the standards for Chinese

patent innovation are not easy to reach, and the new drug approval system does not fit the characteristics of Chinese patent medicine [19]. It should be promoted as soon as possible to establish an approval mechanism that meets the characteristics of traditional Chinese medicine.

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