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The Impact of R&D Investment on Export Trade: A Study Based on Innovative Pharmaceutical Companies at Different Development Stages in Jiangsu Province Exploratory Multiple-case Study

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Abstract: This study examines the impact of R&D investment on the export performance of innovative pharmaceutical enterprises and challenges the conventional wisdom that increased R&D spending invariably boosts exports. Utilizing a mixed-methods approach, we conducted an exploratory multi-case analysis coupled with linear regression modeling, focusing on three representative Jiangsu-based firms—Hengrui pharmaceutical (mature), Xinda biology (growing), and Zejing pharmaceutical (start-up)—over the period 2020–2024. Robustness was assessed via stepwise, ridge, and ordinary least squares regressions. Results indicate that R&D intensity lacks a statistically significant direct effect on export volume, with positive signals emerging only under stepwise regression and failing to demonstrate cross-method robustness. Conversely, firm size exhibits a stable positive correlation with exports post-collinearity adjustment, while the asset-liability ratio exerts a limited negative influence. Notably, no significant export disparity was observed across firms at varying developmental stages. These findings refute the deterministic view of R&D-driven export growth, highlighting instead the contingent nature of this relationship, mediated by factors such as R&D cycles, international regulatory approval, and market access barriers. The study offers nuanced insights for optimizing R&D allocation and export strategies tailored to corporate lifecycle stages, alongside theoretical implications for industrial policy formulation.

1. Introduction

Nowadays, the competition pattern of the national pharmaceutical market is undergoing profound changes. The R&D strength of innovative drugs and the international export ability of products have already become an important standard to measure the core competitiveness of the entire pharmaceutical industry. Jiangsu is a major pharmaceutical industry province worthy of the name in China. It has gathered a large number of innovative pharmaceutical enterprises such as Hengrui pharmaceutical and Xinda biology, which are at the forefront of the country. Both the R&D

investment of enterprises and the export scale of products are in the leading position in the country. According to the traditional international trade theory, combined with the research experience of most manufacturing industries, R&D investment has always been the core driving force for enterprises to carry out export trade [1][10]: Enterprises' increasing R&D investment can effectively improve the technical content and innovation level of products, so as to accumulate stronger competitiveness in the international market and ultimately realize the expansion of export scale [7].

However, the pharmaceutical industry has a very distinctive particularity. It not only has a long R&D cycle and high investment risk, but also faces strict industry regulation. Product approval and listing also takes a lot of time, which leads to the traditional theory that "R&D investment can promote export" is still applicable in the pharmaceutical industry, which has become a problem that needs to be re verified. In the actual operation process, we can see many contradictions: some innovative pharmaceutical enterprises have maintained high R&D investment all year round, but their export performance has always failed to meet expectations; On the contrary, some enterprises with obvious scale advantages, even if their R&D investment is not top in the industry, have realized the rapid growth of export scale by relying on mature overseas sales channels and perfect market layout. In recent years, domestic studies have pointed out that the trend of "building walls and barriers" for Chinese pharmaceutical enterprises in Europe and the United States has become increasingly obvious, and the approval barriers, capital barriers and pricing interference faced by pharmaceutical enterprises can not be ignored [6]. Moreover, the current research on the relationship between R&D and export of pharmaceutical enterprises is mostly a large-scale empirical analysis. There are few in-depth studies on enterprises in specific regions and at different stages of development. It is difficult to clarify the complex relationship between R&D and export in the pharmaceutical industry.

Based on this reality, this paper focuses on the innovative pharmaceutical enterprises in different stages of development in Jiangsu Province, and mainly wants to clarify three questions: under the special development background of the pharmaceutical industry, what is the actual impact of R&D investment on the export trade of enterprises? What factors hinder R&D investment from promoting exports? What are the core factors that can really drive the export growth of pharmaceutical enterprises at this stage? We hope that by answering these questions, we can provide practical theoretical reference and practical basis for pharmaceutical enterprises to optimize their R&D and export strategies, and the government to formulate industrial support policies that are more suitable for the needs of the industry.

2. Literature Review

2.1 Research on R&D Investment and Export Trade of Enterprises

(1) Current situation of relevant research abroad

Foreign scholars' research on the relationship between R&D investment and export behavior of enterprises started earlier and is relatively systematic in theory. Wakelin (2001) analyzed the data of British manufacturing enterprises and found that R&D expenditure had a significant positive impact on productivity growth, and after productivity increased, exports also increased [10]. Cassiman and golovko (2011) noted that innovation and export are not one-way, but two-way interaction, but the strength of the interaction will be affected by the industry's technology intensity and market access conditions [8]. Aw, Roberts and Xu (2011) have experimented with American enterprise data and found that there is an obvious self selection effect between R&D investment and export decision-making. The more R&D investment, the more likely it is to enter the international market [9]. As for the pharmaceutical industry, Dutta et al. (2016)'s research on Indian pharmaceutical enterprises shows that there is indeed a positive correlation between R&D intensity and exports, but the size of enterprises and product structure will adjust this relationship [12]. Guan and MA (2019) also found in

their analysis of Chinese enterprises that the driving effect of innovation capability on export performance varies widely among different industries, and the chain of high-tech industries is longer and more uncertain [7]. Jiang et al. (2024) reviewed the cross-border authorization transactions of Chinese pharmaceutical enterprises from 2019 to 2023, and found that the number of innovative drugs authorized abroad has continued to exceed the number of imported drugs, and external authorization is becoming an important way for pharmaceutical enterprises to go to sea [11]. On the whole, the foreign literature generally recognizes the positive effect of R&D investment on exports, but they do not deny that this effect will vary according to different industries, and there is also a lag in time.

(2) Domestic related research status

Domestic related research mainly focuses on the data of Chinese enterprises, focusing on how R&D investment affects export performance. Liuqiren et al. (2023) took the reform of the recognition conditions of high-tech enterprises as the starting point, and found that tax incentives can significantly stimulate the R&D expenditure of enterprises, thereby improving the export performance [1]. Jiangbin (2014) also confirmed the positive relationship between R&D investment and exports of high-tech enterprises with empirical data at the provincial and municipal levels in Zhejiang [3]. When studying how long Chinese enterprises' exports can last, chenyongbing et al. (2012) found that the duration of enterprises' exports is generally not long, and the R&D and innovation ability is an important factor in prolonging this cycle [4]. Sunchuren et al. (2015) pointed out that there is a close relationship between the quality of export products and the level of industrial agglomeration [5]. In the pharmaceutical industry, Wang Jing (2025) systematically sorted out the current situation and problems of the internationalization of China's biomedical industry, and mentioned that the development of innovative drugs listed overseas is considerable, but the trend of European and American countries to build barriers and walls for Chinese pharmaceutical enterprises is also more and more obvious, with inevitable obstacles such as approval barriers, capital barriers and pricing interference [6]. Zhangcongshan et al. (2024) analyzed the biomedical industry in Jiangsu free trade zone and showed that institutional innovation was conducive to the external development of innovative pharmaceutical enterprises, but there were still many loopholes to be filled in the links of standard docking and approval coordination [2]. Generally speaking, most domestic literatures agree that R&D investment is conducive to the export performance of enterprises, and are also gradually paying attention to the relationship between R&D and export in special industries such as pharmaceutical enterprises.

2.2. Research on R&D and International Development of Innovative Pharmaceutical Enterprises

(1) Current situation of relevant research abroad

Foreign scholars' research on R&D and international development of pharmaceutical enterprises is mainly carried out from the perspective of self selection effect of R&D investment and industry particularity. Aw, Roberts and Xu (2011) found that there is an obvious self selection effect between R&D investment and export decision, and enterprises with higher R&D investment are more likely to enter the international market, especially in high-tech industries such as medicine [9]. Wakelin (2001)'s analysis of the UK's manufacturing industry also points to a similar logic. R&D expenditure indirectly promotes export expansion by improving productivity, and this mechanism is more obvious in R&D intensive industries [10]. Dutta et al. (2016)'s research on Indian pharmaceutical enterprises further confirmed that there was a significant positive correlation between R&D intensity and export, but the relationship between the two was moderated by enterprise size and product structure, indicating that the driving force of R&D on export in the pharmaceutical industry was not a simple linear relationship [12]. Guan and MA (2019) pointed out in their research on Chinese enterprises that the promotion effect of innovation capability on export performance varies significantly among different industries. The

transformation chain of high-tech industries is longer and the uncertainty is higher [7]. Cassiman and golovko (2011) emphasized that there is a two-way interaction between innovation and export, and the strength of this relationship is restricted by industry technology intensity and market access conditions [8]. Overall, while affirming the positive effect of R&D on exports, foreign literature also points out the special challenges of the pharmaceutical industry in terms of transformation efficiency and market access.

(2) Domestic related research status

Domestic scholars have carried out rich research on the international development of Chinese innovative pharmaceutical enterprises in recent years. Chenyongbing et al. (2012) found that the export duration of Chinese enterprises is generally short, and the R&D and innovation ability is an important factor to extend the export duration. This conclusion also has reference significance for pharmaceutical enterprises [4]. Sunchuren et al. (2015) showed that the quality of export products is closely related to the level of industrial agglomeration. Similarly, the internationalization of pharmaceutical enterprises also needs the strong support of industrial clusters [5].

In terms of targeted research on the pharmaceutical industry, Wang Jing (2025) systematically reviewed the current situation and challenges of the international development of China's biomedical industry, and pointed out that while the overseas listing of innovative drugs is booming, the trend of European and American countries to "build walls and barriers" for Chinese Pharmaceutical Enterprises is also increasingly obvious. The overseas market barriers faced by pharmaceutical enterprises include approval barriers, capital barriers and pricing interference. These external constraints have significantly prolonged the cycle of R&D investment to export [6]. Zhangcongshan et al. (2024) pointed out in their research on the biomedical industry in Jiangsu free trade zone that institutional innovation plays a positive role in promoting the internationalization of pharmaceutical enterprises, but there are still shortcomings in standards docking and approval coordination [2]. Jiang et al. (2024) analyzed the cross-border authorization transactions of Chinese pharmaceutical enterprises from 2019 to 2023 and found that the number of external authorizations in the field of innovative drugs in China has continued to exceed the number of imports. External authorizations are becoming an important path for pharmaceutical enterprises to go to sea, which provides a reference for differentiated internationalization models for pharmaceutical enterprises at different stages of development [11]. To sum up, while affirming the core driving role of R&D investment in the internationalization of pharmaceutical enterprises, domestic research has increasingly focused on the regulatory role of overseas market barriers, institutional environment and enterprise development stage differences on the relationship between R&D and export.

2.3. Research Review

From the existing literature, scholars at home and abroad have indeed accumulated a lot of achievements around the topics of R&D investment and enterprise export, and the internationalization of innovative pharmaceutical enterprises. Most of the studies have recognized that R&D investment has a positive role in promoting exports, but also noted the differences between industries and the lag in time, which provides a solid starting point for this study.

However, after consulting these literatures, we found that there are still some deficiencies in the existing research: first, most of the research is focused on the whole industry or the overall manufacturing industry, but the pharmaceutical industry, especially the innovative pharmaceutical enterprises, has the characteristics of high-tech, strict supervision and long-term fields, so it is inevitable to be lack of pertinence to summarize with general conclusions; Second, most of the existing studies are analyzed from the overall level of enterprises, ignoring that enterprises have different characteristics at different development stages. These studies are difficult to reflect the

different effects of R&D investment on export trade at different development stages and life cycles; Third, most of the current research uses the research method of large sample empirical analysis, and the in-depth research on the relevant representative enterprises is not in place, so the guiding significance of the suggestions for the relevant enterprises will be very limited.

Because of these gaps in front of us, this paper focuses on the innovative pharmaceutical enterprises in different stages of development in Jiangsu Province, and specifically selects the method of multi case exploration combined with empirical test to deeply analyze the impact mechanism of R&D investment on export trade and the differences in different stages, which not only makes up for the shortcomings of existing research, but also provides a meaningful reference for innovative pharmaceutical enterprises to optimize their R&D layout and how to improve their export level.

3. Research Design

3.1. Sample Selection and Data Sources

This paper uses the method of multi case exploration and analysis, and selects three innovative drug listed companies in Jiangsu Province, Hengrui pharmaceutical, Xinda biological and Zejing pharmaceutical. These three companies are at different stages. Hengrui is relatively mature, Xinda is in the growth stage, and Zejing is still in the start-up stage. Their investment in R&D and the degree of overseas market expansion are not the same. They are both representative and can be seen by comparison. They are quite suitable for multi case studies. The time window is set for 2020 to 2024. The three companies have a total of 15 initial observation points, which can roughly describe the business change trend in these five years.

For the division of the development stages of the three enterprises, this paper is mainly based on the enterprise life cycle theory and comprehensively judged from the following three dimensions:

(1) Years of establishment and business volume of the enterprise. Founded in 1970, Hengrui pharmaceutical is a typical mature enterprise with a total assets of more than 10 billion yuan and a long operation time and large volume; Founded in 2011, Cinda biological has rapidly expanded its asset scale, and its product pipeline is being commercialized from clinical practice, which is in line with the characteristics of the growth period; Although Zejing pharmaceutical was established in 2009, its first product was approved to be listed before or after 2020. Its asset scale is small, and it is still a start-up enterprise based on R&D investment and initial operation of the product.

(2) Is the revenue structure and profitability. Hengrui generic medicine is parallel to the original drug, with stable income structure, continuous profitability for many years, abundant cash flow, and financial maturity; Cinda bio has launched its products in recent years, and its revenue has increased rapidly, but it still suffers losses as a whole, which is a typical performance of the growth period of "increasing revenue without increasing profits"; Zejing pharmaceutical achieved its first product sales around 2020. It is small and unprofitable. It relies on external financing to support research and development, which is in line with the financial characteristics of start-up enterprises.

(3) It is the maturity and internationalization process of R&D pipeline. Hengrui pharmaceutical has a rich pipeline under development. Several original research drugs have been listed in China, and some have been promoted to the overseas clinical or approved stage. The export of generic drugs has reached a scale, but the overseas commercialization of original research drugs is still in the early stage; Cinda bio's core products are mainly in the domestic market, and its internationalization mainly adopts the license out mode. It has not yet realized the direct overseas registration and large-scale export of products, and is in the exploration stage of overseas expansion; Zejing pharmaceutical's R&D efforts are concentrated in China. The overseas patent layout and international multi center clinic have not yet started. The overseas sales revenue is almost zero, and the internationalization is still in the preparation stage before the start.

Based on the above judgment, this paper classified Hengrui pharmaceutical as a mature innovative pharmaceutical enterprise, Xinda biological as a growing innovative pharmaceutical enterprise, and Zejing pharmaceutical as a start-up innovative pharmaceutical enterprise. This division provides a clear clue for the subsequent cross case comparison, and also facilitates the understanding of the impact of R&D investment on export trade from the perspective of development stage differences.

The core data of this study are obtained through public traceable channels, including:

(1) Annual report of the enterprise: obtained through the official websites of Shanghai Stock Exchange and Shenzhen Stock Exchange and the official investor relations platform of the enterprise, which is the first-hand financial and operating data officially disclosed by the enterprise.

(2) Dongfang fortune.com: a professional financial data platform that provides standardized collation and cross validation of enterprise financial indicators and business data.

(3) Flush Ifind financial database: a domestic authoritative financial data service provider, which provides standardized and unified financial data support for research.

The data cover R&D expenses, overseas sales revenue, total assets at the end of the year, total liabilities at the end of the year, total operating income and other financial indicators. The data are authentic and traceable, and the statistical caliber is unified, providing reliable data support for multi case analysis and empirical testing.

3.2. Variable Definition

Variable selection follows the principle of "scientificity, measurability and data availability". The explained variable is export trade, the core explanatory variable is R&D investment, the control variable is included in the enterprise scale and asset liability ratio, and a dummy variable is set to control the individual differences of enterprises.

(1) Export trade (lnOversea). This variable is measured as the natural logarithm of overseas sales revenue. The overseas sales revenue directly reflects the international market sales scale of the enterprise's products. The data are regularly disclosed in the annual report, and the statistical caliber is unified. For the observation value with zero overseas sales revenue, taking its logarithm will produce a missing value, which will be eliminated in the regression.

(2) R&D investment (lnRD). This variable is measured as the natural logarithm of total R&D expenditure. Technological innovation theory believes that R&D investment is the key to the formation of core competitiveness of enterprises, and heterogeneous enterprise trade theory further points out that R&D investment can help enterprises break through the sunk cost of exports and enter the international market.

(3) Enterprise size (lnSize). This variable is measured as the natural logarithm of year-end total assets. The heterogeneous enterprise trade theory shows that the larger the scale of enterprises, the more qualified they are to bear the cost of overseas market development. This variable is introduced to strip the impact of scale effect on exports.

(4) Asset liability ratio (Lev). This variable is measured as year-end total liabilities divided by year-end total assets, multiplied by 100%.The enterprise life cycle theory points out that there are differences in the financing structure of enterprises at different stages, and excessive financial leverage may restrict exports. This variable is introduced to control the impact of financial status.

(5) Dummy variables (D1, D2). D1 corresponds to Hengrui Pharmaceutical (Hengrui pharmaceutical=1, others=0), D2 corresponds to Xinda biology (Xinda biology=1, others=0), and Zejing pharmaceutical is the benchmark group. According to the enterprise life cycle theory, pharmaceutical enterprises at different stages have essential differences in R&D and export, and virtual variables are introduced to control the individual effect of enterprises. The type, name, symbol and measurement method of each variable are summarized in Table 1.

Table 1: Variable definition table

Variable type	Variable name	Variable symbol	Variable measurement method
Explained Variable	Export trade	lnOversea	The natural logarithm of overseas sales revenue eliminates dimensionality and heteroscedasticity effects, enabling the measurement of a company's export trade scale and capacity.
Core Explanatory Variable	Research input	lnRD	The natural logarithm of total R&D expenditure eliminates dimensional and heteroscedasticity effects, enabling an accurate measurement of a company's R&D investment intensity and innovation capacity.
Controlled Variable	Firm size	lnSize	The natural logarithm of total assets at year-end measures the overall scale of an enterprise and assesses the impact of scale effects on export trade.
Controlled Variable	Asset-liability ratio	Lev	Total liabilities at year-end / Total assets at year-end × 100% measures the enterprise's financial leverage ratio and assesses how its financial condition impacts export trade.
Dummy Variable	The Individual Effect of Enterprises	D1, D2	DD1: Hengrui Pharmaceuticals = 1, others = 0; D2: Innovent Biologics = 1, others = 0; Zejing Pharmaceuticals served as the baseline group.

Supplementary instructions for variable selection:

In terms of variable selection, this paper follows the common practice of previous studies, and makes reasonable adjustments in combination with data availability and research scope

(1) Description of R&D investment indicators: in theory, the impact of R&D investment on enterprise exports is not just based on the "quantity" of investment, but also on the "quality" (such as technological innovation and R&D efficiency) and "direction" (such as whether to carry out international multicenter clinical trials for overseas markets). However, due to the availability of data, this paper only measures from the "quantity" dimension of investment scale, without further distinguishing the quality and direction of R&D.

(2) Description of selection of control variables: This paper has included common control variables such as enterprise size and asset liability ratio to reduce the estimation deviation caused by missing variables. Also limited by the data and research scope, there are no factors that may affect the company's age, profitability (ROA), internationalization experience, etc.

3.3. Model Construction

In order to more accurately measure the actual impact of R&D investment on the export trade of innovative pharmaceutical enterprises, and to control the interference of individual differences of enterprises on the regression results, this paper takes Zejing pharmaceutical as the benchmark group, introduces dummy variables D1 and D2 corresponding to Hengrui pharmaceutical and Xinda biology respectively, and constructs the linear regression model as follows

$$\ln \text{Oversea} = \alpha_0 + \beta_1 \ln \text{RD} + \beta_2 \ln \text{Size} + \beta_2 \text{Lev} + \beta_2 \text{D}_1 + \beta_2 \text{D}_2 + \varepsilon \quad (1)$$

Including:

α_0 is the constant term of the model, representing the basic level of export trade of the benchmark group (Zejing pharmaceutical).

$\beta_1 - \beta_5$ is the regression coefficient of each variable, which reflects the influence degree and direction of the variable on export trade (β 1 is the core concern coefficient, which reflects the driving effect of R&D investment on export trade).

ε is a random disturbance term, representing other factors affecting export trade not considered in the model (such as overseas market policies, exchange rate fluctuations, etc.).

Zejing pharmaceutical was selected as the benchmark group, mainly from the following three points: first, Zejing pharmaceutical started its overseas business the latest among the three enterprises, and its export income was almost zero, which was equivalent to the state of "R&D investment has not yet been transformed into export". Taking it as a benchmark can provide a clean reference baseline, and the virtual variable coefficients of Hengrui medicine and Cinda biology can be directly explained as the export differences relative to this baseline. Second, according to the enterprise life cycle theory, Zejing pharmaceutical is the only start-up enterprise in the three samples, with limited resources and the overseas layout has not yet been started. It is suitable to be used as the starting point in the phased comparison framework, so that the growth and mature enterprises can form a contrast with the start-up period. Third, Zejing pharmaceutical has zero overseas sales revenue during the sample period, which will produce missing values after taking logarithms. Setting it as the benchmark group can avoid a significant reduction in the sample size of the reference group, which is conducive to the stability of model estimation under the condition of small samples. On the whole, this choice has corresponding support in the research logic, theoretical basis and statistical processing.

4. Empirical Results and Analysis

4.1. Overall Model Fitting and Collinearity Diagnosis

In order to confirm whether the model as a whole is effective and check whether there are serious multicollinearity problems between the models, as well as provide technical clues for the later explanation of "variable is not significant", this paper uses SPSS AU to carry out linear regression analysis, and the results are as follows:

(1) See Table 2 for model fitting characteristics.

Table 2: Model fitting characteristics

Index	Numerical value
R^2	0.988
Adjust R^2	0.978
F	98.348
p(F test)	0
D-W	2.014
Effective sample size	12

Note: the dependent variable is InOversea

It can be seen from the above table that the adjusted R^2 reaches 0.978, indicating that the explanatory variables together can explain the 97.8% change of export trade, with a high degree of fitting. The F value is 98.348, the p value is 0.000 and less than 0.05, the model is significant on the whole, and there is a statistical quantitative correlation between the explanatory variables and export trade. The D-W value is 2.014, very close to 2, indicating that there is no obvious autocorrelation problem in the residuals, and the model setting is basically reliable.

(2) See Table 3 for multicollinearity diagnosis.

Table 3: Multicollinearity diagnosis

Variable	VIF	Tolerance
lnRD	47.127	0.021
lnSize	97.294	0.01
Lev	17.161	0.058
D1	210.192	0.005
D2	74.78	0.013

Note: in general, when VIF>10 or tolerance<0.2, it is considered that there is serious multicollinearity.

The VIF values of all explanatory variables were far more than 10, the highest was D1 reached 210.192, and the lowest Lev was 17.161; The tolerance is all lower than 0.2, and the lowest is only 0.005. This shows that the multicollinearity problem in the model is quite serious, which will enlarge the standard error of the regression coefficient and lower the T value, making it difficult for some variables' real impact on export trade to pass the significance test. This technical interference is a factor that cannot be ignored in this quantitative analysis, and also provides a basis for the necessity of subsequent robustness test.

4.2 Variable Significance Analysis

In order to answer the research question of this paper - the impact of R&D investment on export trade, observe the performance of control variables and dummy variables, and provide direction for subsequent cause analysis, next, pay attention to the test whether the impact of explanatory variables on export trade is significant.

The specific results of linear regression analysis are shown in Table 4 below, with p<0.05 as the significance test standard。

Table 4: Results of linear regression analysis

Variable	B (Unstand.)	Std. Error	Std. Coef.	t	p	VIF	Tolerance	95% CI
Constant	1.83	1.56	—	1.17	0.29	—	—	[-1.991, 5.653]
lnRD	0.38	0.61	0.19	0.61	0.56	47.13	0.02	[-1.127, 1.879]
lnSize	-0.54	0.80	-0.30	-0.67	0.53	97.29	0.01	[-2.494, 1.420]
Lev	-0.08	0.02	-0.71	-3.85	0.01**	17.16	0.06	[-0.133, -0.030]
D1	2.52	2.44	0.68	1.04	0.34	210.19	0.01	[-3.430, 8.485]
D2	4.28	1.45	1.14	2.95	0.03*	74.78	0.01	[0.726, 7.833]

Note: 1. B (Unstand.) = Non-standardized coefficient; Std.Error = Standard Error; Std. Coef. = Standardization Coefficient Beta; 95% CI = 95% Confidence Interval.

2. The dependent variable is ln overseas, and Zejing pharmaceutical is the benchmark group. The benchmark effect is reflected by the constant term, and no dummy variable is set separately.

3. *p<0.05，**p<0.01.

4. Three invalid samples were logarithmically missing due to zero overseas sales revenue of Zejing pharmaceutical, and have been automatically removed.

The influence of each variable is as follows:

(1) Core explanatory variables. The regression coefficient of lnRD was 0.376, the standard error was 0.614, the T value was only 0.612, the corresponding p value was 0.563, which was much higher than the significance threshold of 0.05, and the 95% confidence interval [-1.127, 1.879] crossed zero. From the regression results, there is not enough evidence to show that R&D investment has a significant impact on export trade. Although the coefficient is positive, it is not statistically significant, so the original hypothesis that "R&D investment has no impact on export" cannot be rejected.

(2) Control variables. The regression coefficient of lnSize is -0.537, the standard error is 0.800, the T value is -0.671, the p value is 0.527, and the 95% confidence interval [-2.494, 1.420] crosses zero, indicating that the enterprise size has no significant linear effect on export trade in this model. Lev's regression coefficient was -0.081, the standard error was only 0.021, the T value was -3.847, and the p value was 0.008. It passed the significance test at the 1% level, and the 95% confidence interval [-0.133, -0.030] completely fell into the negative value interval, indicating that the asset liability ratio had a significant negative impact on export trade, and the standardization coefficient beta was -0.714, which was the largest absolute value in the respective variables, indicating its relative explanatory power on export was strong.

(3) Dummy variable. The regression coefficient of D1 is 2.528, the standard error is as high as 2.435, the T value is only 1.038, the p value is 0.339, and the 95% confidence interval [-3.430, 8.485] has a large span and crosses the zero point, indicating that there is no statistically significant difference between Hengrui pharmaceutical and Zejing pharmaceutical in the export level. The regression coefficient of D2 was 4.280, the standard error was 1.452, the T value was 2.947, the p value was 0.026, which was significant at the 5% level, the 95% confidence interval [0.726, 7.833] did not cross the zero point, and the standardization coefficient beta was 1.142, which was the largest in the respective variables, indicating that Xinda biological had a significant positive difference in the export level compared with Zejing pharmaceutical.

4.3. Analysis of the Reasons for the Inconspicuous Regression Results

Combined with the actual performance of the three pharmaceutical companies in the previous exploratory analysis of multiple cases and the multicollinearity diagnosis results of the model, this section analyzes the regression results from four aspects: industry characteristics, enterprise heterogeneity, external barriers and technical interference.

4.3.1. The Long R&D Cycle of the Pharmaceutical Industry and the Strong Lag of Export Transformation

The most direct reason why lnRD is not significant is the time rhythm of the pharmaceutical industry itself. From the establishment of an innovative drug to its real sale in the overseas market, it needs to go through multiple links of authoritative approval, such as domestic clinical, overseas patent layout, international multi center trials, FDA or EMA approval. This study only takes the period from 2020 to 2024. Most of the R&D expenditures of the three enterprises during the observation period were spent on domestic clinical and registration links, and the whole chain transformation of overseas exports has not been completed. The success of R&D is difficult to be reflected in the growth of overseas sales revenue in the short term. This means that there is a long transmission process between the current R&D investment and the current overseas sales revenue. The direct correlation between the current lnRD and the current lnOversea is diluted by this conduction process. Although the coefficient of inRD in the regression result is positive, it is not significant, just indicating that the promotion of R&D investment on exports at the current stage has not yet formed a statistically visible effect.

4.3.2. The Development Stages of Export Trade of Sample Enterprises Differ Significantly and the Transformation Efficiency is Low

The large internal differences among sample enterprises are also an important reason that hinders the overall explanatory power of lnRD. Hengrui pharmaceutical has the largest export volume among the three, but it mainly relies on generic drugs. Innovative drugs are still in the early stage of large-scale overseas, and the export conversion efficiency of R&D investment is limited. Xinda bio follows the license out route. Its overseas revenue mainly comes from technology licensing rather than direct export of products. Although the source of funds is related to R&D, the transmission path is longer, so the chain between lnRD and lnOversea is stretched. As the benchmark group, Zejing pharmaceutical's overseas sales revenue was almost zero in the sample period, and its R&D investment was all concentrated in the domestic clinical and registration. There was basically no corresponding relationship between lnRD and lnOversea. The differences in export orientation among the three enterprises and the generally low conversion rate make it difficult for lnRD to show a significant effect in the overall model. It is worth noting that D2 is significantly positive in the regression result, and Xinda biology shows a significant difference in the export level compared with Zejing pharmaceutical, indicating that the export difference caused by the development stage exists in part of the comparison, but the non significant of D1 also indicates that this difference does not occur in all enterprises.

4.3.3. Multiple Barriers in Overseas Pharmaceutical Market Form Strong Constraints

The overseas pharmaceutical market has high barriers in technology, patents, approval and channels, which is an important external reason why inRD is difficult to transform into lnOversea growth. Regulators in mainstream markets such as Europe and the United States have strict requirements on the effectiveness and safety of drugs, and the approval process is cumbersome, time-consuming and costly. In addition, local pharmaceutical enterprises have built a high wall in the patent layout, and domestic enterprises often face considerable patent risks and litigation costs when promoting overseas commercialization. Even if the product gets the approval, the subsequent establishment of localized sales channels and brand awareness will require a lot of time and capital investment. The superposition of multiple factors has raised the actual threshold for the transformation of R&D investment into exports, and the positive driving effect of lnRD on lnOversea has been significantly weakened.

4.3.4. Significant Technical Interference of Model Multicollinearity

From the collinearity diagnosis results, the VIF values of all explanatory variables are far greater than 10, which has a serious problem of multicollinearity. Multicollinearity will increase the standard error of regression coefficient, reduce the T value, and reduce the significance level of variables, making the possible influence relationship unable to pass the significance test. Although this problem does not change the basic quantitative relationship between variables, it directly affects the significant results of the empirical test and becomes a technical key factor that does not form a significant correlation between various variables and export trade.

5. Robustness Test

The results of the main regression were interfered by multicollinearity, and the standard error of each variable was significantly enlarged, so the judgment of significance became unreliable. In order to sift out the conclusions that are still tenable across methods and eliminate the results that may be accidentally run out by single regression, this chapter uses three methods for cross validation: stepwise

regression, ridge regression and ordinary linear regression. The logic of the three methods to deal with collinearity is not the same - stepwise regression is to directly eliminate the variables with insufficient significance, ridge regression is to introduce a little error into the estimation to change the coefficient more stable, and ordinary linear regression is to reduce the source of collinearity by simplifying the variables. If the direction and significance of a variable under the three methods are basically the same, the conclusion will be relatively stable.

5.1. Robustness Test Design

5.1.1. Inspection Logic

Keep the explained variable unchanged, only change the estimation method, and compare the coefficient direction and significance of lnRD, lnSize, Lev, D1 and D2 under different methods. The focus is on whether the insignificance of lnRD is tenable under any method and whether the significance of Lev and D2 is stable across methods.

5.1.2. Specific Method Selection

(1) Stepwise regression. By gradually screening and automatically identifying the variables that have a significant impact on export trade, and eliminating the variables with insufficient explanatory power, the interference of collinearity can be alleviated to a certain extent. The entry criteria were $p<0.05$ and the exit criteria were $p>0.1$.

(2) Ridge regression. The ridge parameter $k=0.010$ is introduced, and all variables are retained but their coefficients are compressed to deal with the multicollinearity problem. The stability of coefficient estimation is obtained by sacrificing partial unbiasedness.

(3) Ordinary linear regression. Only the core variables that are relatively stable in the first two methods are included, and the relationship between variables and export trade is tested again without introducing too many collinearity sources.

5.2. Robustness Test Results

5.2.1. Stepwise Regression Analysis Results

The results of stepwise regression analysis are shown in Table 5.

Table 5: Results of stepwise regression analysis

Variable	B (Unstand.)	Std. Error	Std. Coef.	t	p	VIF	Tolerance
Constant	0.516	0.74	—	0.697	0.506	—	—
lnRD	0.551	0.164	0.276	3.349	0.010*	3.754	0.266
Lev	-0.095	0.011	-0.836	-8.721	0.000**	5.089	0.196
D2	2.787	0.22	0.744	12.543	0.000**	1.948	0.513
R^2	0.986						
Adjust R^2	0.98						
F	181.94						
p	0						
D-W	2.046						

Note: 1. B (Unstand.) = Non-standardized coefficient; Std. Error = Standard Error; Std. Coef. = Standardization Coefficient Beta.

2. The dependent variable is lnOversea, n=12, *p<0.05, **p<0.01.

lnSize and D1 do not enter the model. After stepwise regression screening, lnRD, Lev and D2 were

retained, and lnSize and D1 were eliminated. The most obvious difference from the main regression is that the p value of lnRD decreased from 0.563 to 0.010, which passed the significance test for the first time, and the coefficient was 0.551. This change shows that the inconspicuous lnRD in the main regression is probably caused by collinearity - there is a high correlation between lnRD and lnSize, D1. When the latter two variables are eliminated, the partial correlation between lnRD and exports is revealed. The coefficient of Lev is -0.095, the p value is still less than 0.01, and the negative impact remains robust. The coefficient of D2 was 2.787, P value was less than 0.01, which was consistent with the direction of the main regression. The VIF value of the model has dropped significantly below 5.089, and the collinearity problem has been effectively controlled in the model.

5.2.2. Ridge Regression Analysis Results

The results of ridge regression analysis are shown in Table 6.

Table 6: Results of ridge regression analysis

Explan. Var.	B (Unstand.)	Standard Error	Std. Coef.	t	p	VIF
Constant	0.246	0.873	—	0.282	0.787	—
lnRD	0.436	0.387	0.218	1.128	0.302	15.584
lnSize	0.086	0.279	0.047	0.307	0.77	9.916
Lev	-0.091	0.012	-0.798	-7.489	0.000**	4.715
D1	0.192	0.628	0.051	0.306	0.77	11.682
D2	2.797	0.42	0.747	6.654	0.001**	5.231
R^2	0.986					
Adjust R^2	0.974					

Note: 1. Explan. Var. = Explanatory Variable; B (Unstand.) = Non-standardized coefficient; Std. Coef. = Standardization Coefficient Beta.

2. The dependent variable is lnOverseas, n=12, k=0.010, *p<0.05, **p<0.01.

Ridge regression retains all five variables and compresses the coefficients by introducing ridge parameters. Compared with the main regression, the VIF value of each variable decreased significantly, lnRD decreased from 47.127 to 15.584, lnSize decreased from 97.294 to 9.916, and D1 decreased from 210.192 to 11.682, indicating that ridge regression did play a role in alleviating collinearity. In terms of significance, Lev and D2 were still significant at 1% level, while lnRD, lnSize and D1 failed the test. It is worth noting that lnRD turns to be significant in the stepwise regression, but it is still not significant in the ridge regression (P=0.302), which shows that the different ways of dealing with collinearity between the two methods lead to the difference in the results - the partial correlation between lnRD and exports is exposed after the highly correlated variables are directly eliminated in the stepwise regression; Although ridge regression compressed the coefficient variance, lnRD was still suppressed in the correlation with other variables.

5.2.3. General Linear Regression Analysis Results

Based on the findings of the first two methods, lnSize is eliminated in the stepwise regression and is not significant in the ridge regression, but it is most severely suppressed by collinearity in the main regression. It is necessary to investigate its effect separately after excluding the main collinearity sources. Therefore, only lnSize and Lev are included in this round to test the performance of the two variables under the condition of low collinearity. See Table 7 for general analysis results.

Table 7: General linear regression analysis results

Explan. Var.	B (Unstand.)	Std. Error	Std. Coef.	t	p	VIF	Tolerance
Constant	-4.53	2.942	—	-1.54	0.158	—	—
lnSize	1.194	0.457	0.66	2.61	0.028*	1.807	0.553
Lev	-0.025	0.029	-0.222	-0.88	0.402	1.807	0.553
R^2	0.681						
Adjust R^2	0.611						
F	9.628						
p	0						
D-W	1.464						

Note: 1. Explan. Var. = Explanatory Variable; B (Unstand.) = Non-standardized Coefficient; Std. Error = Standard Error; Std. Coef. = Standardization Coefficient Beta.
2. The dependent variable is lnOversea, n=12, *p<0.05, **p<0.01.

After only lnSize and LEV are included, the Vif is reduced to 1.807, and the collinearity problem is basically eliminated. The coefficient of lnSize was 1.194 and the p value was 0.028, which passed the significance test at the 5% level. This shows that when the collinearity sources such as lnRD, D1 and D2 are removed, the positive driving force of enterprise size on exports can indeed be identified, and the insignificant lnSize in the main regression is indeed the product of collinearity suppression. The performance of Lev in this model has changed significantly: Although the coefficient is still negative (-0.025), the p value rises to 0.402, which is no longer significant. This shows that the significance of Lev depends on the co-existence of other variables to a certain extent, and the stability in the simplified model is insufficient, so the interpretation of its negative effect needs to be more careful.

5.3. Inspection Conclusion

Combining the results of stepwise regression, linear regression and ridge regression, the following core conclusions are drawn:

First, the significance of lnRD fluctuates with different methods. In the stepwise regression, lnRD passed the significance test of 5%, and the coefficient was positive, indicating that after removing lnSize and D1, the partial correlation between lnRD and exports did exist. But when switching to ridge regression, the same five variables are in the model, and the p value of lnRD returns to 0.302, which is not significant. This situation shows that the effect of lnRD can be revealed only when highly correlated variables are removed or suppressed. Therefore, it can be concluded that lnRD may have a positive impact on exports, but under the current sample structure and variable setting, this effect is not robust.

Second, Lev's negative effect maintained a significant negative effect in both stepwise regression and ridge regression, but was no longer significant in the linear regression of the simplified model. This shows that the asset liability ratio may have an inhibitory effect on exports, but more evidence is needed to conclude that "the higher the asset liability ratio, the worse the export".

Third, about the scale of enterprises. lnSize was eliminated in stepwise regression, which was not significant in ridge regression, but significantly positive in ordinary linear regression. This shows that the effect of scale exists, but it is easily masked by the collinearity of other variables in the full variable model. Considering the fact that Hengrui pharmaceutical has the largest scale and the largest export volume among the three enterprises, the driving effect of scale is logically reasonable.

Fourth, D2 maintains a significant positive effect at the level of 1% in both stepwise regression and ridge regression, and the coefficient is stable at about 2.8, which is the most stable variable in this robustness test. The difference between Xinda biology and Zejing pharmaceutical in the export level

can be reliably identified under three different estimation methods, which shows that the difference is obvious enough and less affected by collinearity.

5.4. Further Discussion on the Difference of Test Results

The test results have shown that the significance of each variable under different methods is not completely consistent. These inconsistencies lead to several issues that need further discussion.

Cross method fluctuation of R&D investment. R&D investment is significant in stepwise regression, but not significant in ridge regression, because the two methods have different strategies for dealing with collinearity. The stepwise regression eliminated the enterprise size and dummy variable D1, cut off the collinearity source, and the partial correlation between R&D investment and export was revealed, while the ridge regression retained all variables, and the correlation still existed, but was moderately compressed. The comparison between the two shows that R&D investment has a positive signal to exports, but the intensity is not enough to pass the test stably in the full variable structure, which is consistent with the long R&D transformation cycle of the pharmaceutical industry.

Cross model attenuation of the significance of asset liability ratio. The asset liability ratio remains significantly negative in the first three methods, but it is no longer significant in the ordinary linear regression. This decline shows that its significance depends on the complete model structure including R&D investment and dummy variables to a certain extent, and its independent explanatory power is limited, so this conclusion should not be over interpreted.

The shielding and release of enterprise scale. The scale of enterprises is not significant in the main regression and ridge regression, but it turns to a significant positive in the ordinary linear regression with a significant mitigation of collinearity. This change is the intuitive evidence of the collinearity masking effect, and also explains why the gradual regression becomes significant after eliminating the size of enterprises - there is a competitive relationship between the two in terms of explanatory power.

Cross method robustness of dummy variable D2. D2 is the only variable that is highly significant in all methods, and the coefficient is stable at about 2.8. This shows that the export gap between Xinda biology and Zejing pharmaceutical is large enough, and changing methods will not affect the conclusion. In contrast to R&D investment and enterprise scale, the effect exists but its intensity is limited, and it is easy to fluctuate when switching methods. D2 provides a reference: when the variable effect is strong enough, collinearity is difficult to cover it up.

6. Research Suggestions

Through the above research conclusions, combined with the current international development trend of the pharmaceutical industry and the different development stages of the three sample enterprises, this chapter provides suggestions from the enterprise level and policy level respectively.

6.1. Enterprise Level: Differentiated R&D and Export Trade Layout Strategy

According to the actual situation of mature, growth and start-up innovative pharmaceutical enterprises, formulate differentiated strategies to improve the efficiency of R&D investment into export.

(1) Mature pharmaceutical enterprises (with Hengrui pharmaceutical as the reference): promote the structural transformation from the export of generic drugs to the export of innovative drugs. The research conclusion shows that scale is the most realistic factor to promote exports at present, but it is difficult to sustain only by scale driven. Mature pharmaceutical enterprises have a certain overseas generic drug export foundation and financial strength, and the next step should focus on the overseas commercialization of innovative drugs. Specifically, first, increase the proportion of overseas oriented

R&D investment, focus on the clinical needs of mainstream markets in Europe and the United States and emerging markets such as ASEAN, and simultaneously promote the layout of overseas patents in the R&D stage; Second, accelerate the overseas approval process of listed innovative drugs, promote the products to pass the authoritative certification of the US Food and Drug Administration or the European drug administration, and establish localized overseas sales channels; Third, take advantage of its scale to obtain market resources and approval experience through overseas cooperation or M&A, and shorten the export transformation cycle of R&D achievements.

(2) Pharmaceutical enterprises in the growth period (with Xinda biology as the reference): promote internationalization with lightweight cooperation mode. Xinda biology's path of realizing overseas income through technology licensing mode has been confirmed as an effective stage strategy by this study. In the growth period, the fund and channel capacity of pharmaceutical enterprises are relatively limited, so it is not suitable to build overseas sales system on a large scale. Suggestions: first, concentrate R&D resources on international core pipelines, and promote clinical trials in accordance with international standards to pave the way for subsequent overseas approval; Second, in the case where the products are not ready for export, we should first develop cooperation with high technology licensing threshold but light mode, and realize light weight going to sea with the help of existing channels and approval experience of overseas pharmaceutical enterprises. At the same time, we can also accumulate capital and international operation experience; Third, we should pay attention to the control of financial leverage. The robustness test has indicated that too high asset liability ratio will restrict exports, and we should take a diversified financing path to ensure the demand for R&D funds.

(3) Start up pharmaceutical enterprises (with Zejing pharmaceutical as the reference): first consolidate the capital, and then layout to the sea. At present, the core task of start-up pharmaceutical enterprises is not to export, but to complete the product listing and clinical verification in the domestic market. However, the layout of going to sea cannot be started until the product is launched. First, we should start overseas patent layout at the early stage of core product development, build a patent protection framework at a lower cost, and reserve space for future overseas expansion; Second, we should concentrate resources to complete the domestic clinical and product listing, form a stable cash flow and technology accumulation, and then gradually start overseas clinical trials and approval; Third, we should take advantage of the advantages of Jiangsu pharmaceutical industry cluster to cooperate with local mature pharmaceutical enterprises or contract R&D and production organization enterprises, indirectly participate in the overseas market, and accumulate experience for the subsequent independent sailing.

6.2. Policy Level: Improve Supporting System to Help Pharmaceutical Enterprises Break Through Overseas Barriers

(1) The results show that overseas market barriers are important external constraints that make it difficult for R&D investment to quickly transform into export growth. The government should provide support from the following aspects:

(2) Increase special support for international R&D. The government should provide financial subsidies and tax incentives for pharmaceutical enterprises in areas such as overseas clinical trials, overseas patent applications, and international drug approvals, in order to reduce the cost pressures associated with international R&D. A provincial special fund for the internationalization of biomedical innovation can be considered to provide financing support for the overseas commercialization of innovative drugs.

(3) Build a one-stop service platform for overseas trade. Led by the government and in collaboration with industry associations, legal service agencies, professional consulting agencies, etc., it provides pharmaceutical enterprises with integrated services such as overseas approval consulting,

patent layout guidance, market access research, and compliance review. At the same time, an early warning mechanism for the risk of overseas pharmaceutical market was established to timely push the information of policy adjustment, patent litigation trends and regulatory rule changes of the target market, so as to help enterprises avoid risks in advance.

(4) Promote the international docking of medical standards. The government should strengthen standard mutual recognition cooperation with major international pharmaceutical markets, promote the alignment of domestic drug R&D and clinical trial standards with those in Europe and the United States, help pharmaceutical enterprises shorten overseas approval cycles, and enhance the international recognition of R&D outcomes. At the same time, with the help of the free trade zone and other institutional innovation platforms, the export approval process of biomedical products is simplified.

(5) Differentiated support policies were issued for enterprises at different stages of development. For mature pharmaceutical enterprises, support should focus on the overseas commercialization of innovative drugs and the development of sales channels. For growing pharmaceutical enterprises, support should focus on advancing international R&D pipelines and overseas collaboration projects. For start-up pharmaceutical enterprises, support should focus on overseas patent portfolio development and core pipeline R&D. The use of policy tools should match the development stage of enterprises.

(6) Strengthen the synergy effect of industrial clusters. Relying on the advantages of the pharmaceutical industry in Jiangsu Province, we should promote the in-depth cooperation between pharmaceutical enterprises, universities, scientific research institutions and contract R&D and production organizations, build an integrated industrial chain from R&D to production and then to export, and provide a more solid industry for the transformation of pharmaceutical enterprises' R&D achievements to export.

7. Conclusion

This paper sets the research window from 2020 to 2024, and selects Jiangsu Hengrui pharmaceutical, Xinda biology and Zejing pharmaceutical, which are listed companies of innovative pharmaceutical enterprises at different development stages, as the research object. In terms of method, instead of taking a single path, it combines multi case exploratory analysis and linear regression empirical test. The whole article discusses the actual impact of R&D investment on the export trade of pharmaceutical enterprises. After model construction, empirical analysis, robustness test, in-depth cause analysis and other links, combined with the different characteristics of the three enterprises in R&D and export trade, the following core research conclusions are drawn:

In the five years from 2020 to 2024, the direct effect of R&D investment on the export trade of these three enterprises is not obvious. Although the coefficient of R&D investment in the main regression is positive, the p value is far from reaching a significant level. In the subsequent robustness test, it is only significant in the stepwise regression. It can be seen that the effect has a positive impact on the signal, but the cross method robustness is insufficient. R&D investment may have a positive impact on exports, but it is not stable enough to stand the test of changing methods. This is different from the traditional expectation that "R&D investment will inevitably promote exports", but it is consistent with the characteristics of the pharmaceutical industry, such as long R&D cycle, lagging export transformation and high overseas barriers.

The scale of enterprises is the core factor to promote export trade at this stage. Although it failed to pass the significance test under the collinearity suppression in the main regression, in the robustness test, the enterprise size was significantly positive in the ordinary linear regression, and was eliminated in the stepwise regression, but there was an explanation for the release of R&D investment effect,

indicating that scale has a substantial role in promoting exports. This conclusion is also consistent with the fact that Hengrui pharmaceutical has the largest scale and the largest export volume.

The asset liability ratio has a negative impact on export trade, and the direction is basically the same under each method, but the independent explanatory power is limited. In the main regression, stepwise regression and ridge regression, the asset liability ratio is significantly negative, but it is no longer significant in the simplified model. This shows that the asset liability ratio has a certain inhibitory effect on exports, but its significance depends on the complete combination of variables to a certain extent.

The heterogeneity of export performance among enterprises is partially established. The export difference between Xinda biological and Zejing pharmaceutical is highly significant under all methods, but the gap between Hengrui pharmaceutical and Zejing pharmaceutical has not passed the test. It shows that the differences of development stages do not appear in equilibrium in all comparisons.

The hybrid method of "case analysis and confirmatory test" used in this paper effectively realizes the complementarity of qualitative analysis and quantitative analysis. The findings of case analysis provide a realistic explanation for the empirical results. The discussion on the robustness of the empirical test in turn deepens the understanding of the characteristics of the case, and provides a reference for the relevant research under the condition of small samples and high collinearity.

Although this study reveals the impact mechanism of innovation driven R&D investment on the export of innovative pharmaceutical enterprises in Jiangsu through multiple case exploration and linear regression hybrid method, the following limitations still exist:

(1) The representativeness and universality of samples are limited. Only three pharmaceutical enterprises at specific stages in Jiangsu Province were selected, which did not cover the pharmaceutical strong provinces such as Guangdong and Shanghai, and the multi segmented fields such as chemical medicine and biological medicine. The conclusion is not universal across regions and industries.

(2) Research cycle and variable dimension limitations. The short-term panel of five years (2020-2024) is difficult to capture the characteristics of long-term and strong lag of pharmaceutical R&D, and the R&D investment only considers the total cost, and does not include the quality (such as patent strength) and direction (such as international multi center clinical); The control variables also do not include key factors such as the age of the enterprise, profitability and international experience, so there is a risk of missing variables.

(3) Model setting and methodological constraints. Due to the limitation of small samples, frontier econometric models such as panel fixed effect or threshold regression cannot be used. Although the interference of multicollinearity on parameter estimation is alleviated by robustness test, it still affects the inference accuracy.

(4) The integration depth of hybrid methods is insufficient: the connection between case analysis and empirical test is still superficial, and the in-depth vertical analysis of single case is lacking, which fails to fully reveal the internal mechanism of R&D investment and export of enterprises at different development stages.

Based on the above deficiencies, future research can be deepened from the following dimensions:

(1) Expand the space-time boundary of the sample. Researchers should construct a heterogeneous sample of small and medium-sized enterprises spanning multiple provinces, subsectors, and industrial clusters to enhance the external validity and industry representativeness of the findings.

(2) Extend observation period and dynamic tracking. Researchers should use long panel data (spanning more than 10 years) to analyze the dynamic lag effects and life-cycle characteristics of the impact of R&D investment on exports.

(3) Optimization model and variable system. By introducing quantitative indicators such as "overseas access index" and the proportion of international clinical investment, combined with panel

fixed effect, threshold regression and other methods, a multidimensional transmission model including exchange rate fluctuations and international cooperation mode is constructed.

(4) Deepen case comparison and mechanism mining. Researchers should conduct in-depth single or multi-case comparisons of domestic and international benchmark enterprises, along with longitudinal tracking of sample enterprises in Jiangsu, to achieve an organic integration of qualitative and quantitative analyses.

(5) Combined with macro policy situation analysis. Embedded in the policy background of the pilot Free Trade Zone, "the belt and road initiative" and RCEP, this paper discusses the regulatory effect of the institutional environment and regional trade agreements on the R&D investment export relationship, and provides the basis for the formulation of industrial policies.

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