The Dynamic Interaction Effects of Government Subsidies, Enterprise Risk-taking and Innovation Performance

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Abstract. Based on the panel data of Shanghai and Shenzhen A-share listed companies in the pharmaceutical manufacturing industry from 2012 to 2021, a PVAR model is established to study the interaction relationship between government subsidies, enterprise risk-taking and innovation performance by using analytical methods such as Granger causality test, impulse response function and variance decomposition. The results of the study show that government subsidies and enterprise risk-taking have a significant inhibitory effect on innovation performance, and enterprise risk-taking has a significant promotional effect on government subsidies.

Keywords: government subsidies; enterprise risk-taking; innovation performance

1 Introduction

The 20th National Congress of the Communist Party of China introduced the concept of "building a healthy China" in its report. The pharmaceutical industry is closely linked to both national development plans and the well-being of the people. As a representative of strategic emerging and high-tech industries, the pharmaceutical manufacturing sector has been prioritized and supported by the government. Government subsidies play a significant role in providing external innovation funds through corporate financing. However, investing in technological innovation carries high risks and uncertainties, which can expose enterprises to operational risks. Therefore, it is important to understand the dynamic relationships between government subsidies, corporate risk-taking, and innovation performance. Thus, the aims of this study are to first examine these relationships and secondly to contribute to government's formulation and implementation of subsidy strategies for pharmaceutical manufacturing enterprises.

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2 Literature Review

2.1 Relationship between government subsidies and corporate risk-taking

Government subsidies can have adverse effects on corporate risk-taking due to "resource crowding" and "resource misallocation". Moderate subsidies tend to increase enterprise risk-taking, whereas excessive subsidies can decrease the level of risk-taking [1]. The introduction of government subsidies disrupts the market economy's order. As a part of non-operating income, subsidies may artificially assist companies in converting losses into profits [2], potentially motivating companies to prioritize rent-seeking, thereby diverting attention and investment away from high-risk endeavors like innovation. Consequently, enterprises in genuine need of support may struggle to obtain the necessary subsidies, resulting in distortions in the allocation of policy resources and rendering subsidy policies ineffective.

2.2 Relationship between government subsidies and innovation performance

Innovation activities can lead to a "free rider" phenomenon among enterprises under the market mechanism [3]. Numerous studies have demonstrated the positive impact of government subsidies in promoting innovation among supported enterprises [4]. However, some scholars argue that government subsidies can have adverse effects on enterprise innovation. They believe that the implementation of subsidy policies may encourage fraudulent subsidies, rent-seeking behavior, manipulation of research and development (R&D), and other undesirable practices [5].

2.3 Research on the relationship between corporate risk-taking and innovation performance

Enterprises that exhibit higher levels of risk-taking tend to favor innovative projects characterized by high risks, lengthy cycles, and advanced technological content. Such projects also offer the potential for greater monopolistic profits, and enterprises can sustain their product innovation efforts by enhancing their corporate risk-taking capabilities [6]. Moreover, the level of risk-taking within an enterprise determines the extent of its innovation activities [7]. However, higher levels of corporate risk-taking are often associated with reduced corporate transparency, leading to more opportunistic behaviors that have a detrimental impact on corporate innovation [8].

Previous research has often overlooked the endogeneity and hysteresis of these three variables, and they have not been examined within the same endogenous system framework. Such an integrated approach would shed light on the dynamic evolution process of their mutual interactions. This study employs the PVAR model to investigate the relationship between government subsidies, corporate risk-taking, and innovation performance. Through an empirical perspective, the research encompasses the impulse response function and variance decomposition analysis of the model to elucidate the dynamic evolution process of the interplay among these variables.

3 Methodology

3.1 Model Setup

This study employs the panel vector autoregressive model (PVAR) to examine the long-term and short-term effects of government subsidies, corporate risk-taking, and innovation performance. The panel vector autoregressive model (PVAR) is a comprehensive equation system that considers all variables as part of an endogenous system. It estimates the impact of lagged variables within the system on a particular variable, capturing the interactive mechanisms among the variables. It is suitable for analyzing panel data with a limited time span, combining the time series VAR model with panel data, and utilizing generalized method of moments (GMM), impulse response function (IRF), and variance decomposition (VD) for analysis. The model takes into account the interactions among the variables and is estimated using the generalized method of moments (GMM) approach. The general equation form of the model is as follows:

$$y_{it} = \alpha_0 + \sum_{j=1}^{n} A_j y_{it-j} + f_i + d_t + \varepsilon_{it} \tag{1}$$

Where y_{it} represents the vector of three endogenous variables, and its expansion can be written as follows:

$$y_{it} = \begin{bmatrix} sub_{it} \\ risk_{it} \\ patent_{it} \end{bmatrix} \tag{2}$$

Where y_{it-j} represents the vector of the three lagged variables, and its expansion can be written as follows:

$$y_{it-j} = \begin{bmatrix} sub_{it-j} \\ risk_{it-j} \\ patent_{it-j} \end{bmatrix} \tag{3}$$

In Equation (1), i and t respectively represent the i the enterprise and the t the year, and j denotes the lag order. The term α_0 represents the intercept of the linear regression equation, A_j represents the regression coefficient matrix, f denotes the fixed effect, d_t represents the time effect, and ε_{it} represents the random disturbance effect. The final expression of the model is as follows:

$$\begin{bmatrix} sub_{it} \\ risk_{it} \\ patent_{it} \end{bmatrix} = \alpha_0 + \sum_{j=1}^{n} A_j \begin{bmatrix} sub_{it-j} \\ risk_{it-j} \\ patent_{it-j} \end{bmatrix} + f_i + d_t + \varepsilon_{it} \tag{4}$$

3.2 Research Variables

Table 1. Research Variables

Variable	Abbreviation	Measurement
Government Subsidies	sub	Ln (The actual amount of government subsidies received by enterprises in the current year)
Corporate Risk-Taking	risk	The volatility of a company's earnings (pre-tax profit) during the observation period multiplied by 100
Innovation Performance	patent	Ln (the total number of patent applications by a company in the current year + 1).

The government subsidy (sub) is represented by the total amount of government subsidy [9]. To mitigate the impact of heteroscedasticity, the index is logged.

The Corporate Risk-Taking (risk) risk is measured based on the degree of fluctuation in a company's earnings [10]. Therefore, this study selects the fluctuation in return on assets (ROA) during the observation period as the dependent variable. ROA is calculated by dividing pre-tax profit by total assets at the end of the year. The adjusted ROA (Adj_ROA) is obtained by subtracting the company's ROA in the current period from the average industry return on total assets for the year. Formula (5) illustrates the specific calculation process for the level of risk-taking. In Equation (6), a rolling basis is used with a three-year observation period to calculate the standard deviation of industry-adjusted ROA, yielding an indicator of the level of risk-taking.

$$\text{Adj\_ROA}_{i,t} = \frac{EBIT_{i,t}}{ASSET_{i,t}} - \frac{1}{X}\sum_{k=1}^{X}\frac{EBIT_{i,t}}{ASSET_{i,t}} \tag{5}$$

$$risk = \sqrt{\frac{1}{T-1}\sum_{t=1}^{T}(\text{Adj\_ROA}_{i,t} - \frac{1}{T}\sum_{t=1}^{T} Adj\_ROA_{i,t})^2} \tag{6}$$

Innovation performance (patent), specifically measured through patent output, is considered the most relevant and direct indicator of R&D alliances [11]. This study focuses on measuring R&D innovation performance based on patent output. Given that invention patents are more indicative of a company's innovation capability, this study utilizes the number of invention patents as a metric for innovation performance. To mitigate the impact of heteroscedasticity, the indicators are subjected to logarithmic transformation after adding 1 [12]. The research variables are as shown in Table 1.

3.3 Data Collection

This study focuses on the pharmaceutical manufacturing industry in the Shanghai and Shenzhen A-share markets, covering the period from 2012 to 2021. To ensure the reliability of the empirical results and remove any potential influence from abnormal samples, several data processing steps were undertaken. Firstly, ST and ST* company samples were excluded from the analysis. Secondly, samples with missing data were eliminated. Lastly, to mitigate the impact of extreme values, the variables were trimmed at the 1st and 99th percentiles. As a result, a balanced panel dataset comprising 80 pharmaceutical manufacturing enterprises and 800 observations was obtained.

The data for this research was sourced from the CSMAR Guotaian database. Specifically, government subsidy data was collected from the financial statement notes in the annual reports of companies, under the category of "non-operating income." The number of patent applications data was obtained from the CSMAR Guotaian database as well, with any missing data manually collected and compiled from the State Intellectual Property Office website.

Stata 17.0 software was used for the empirical analysis. Table 2 presents the statistical characteristics and correlation coefficients of the main variables in the study.

Table 2. Descriptive Statistics of Variables

Variable	N	mean	sd	min	max
sub	800	16.34	1.407	11.72	19.19
risk	800	2.863	2.988	0	15.16
patent	800	2.249	1.320	0	5.030

3.4 Data Collection

Panel Unit Root Test.

Considering the potential issue of spurious regression caused by non-stationary variables, as well as the impact of variable stationarity on the estimation results of the PVAR model and the analysis of impulse response function, it is important to ensure the stationarity of the panel data. To address this, three commonly used panel data unit root test methods, namely LLC, IPS, and Fisher-ADF, are employed to test the stationarity of the aforementioned variables. As shown in Table 3, the null hypothesis of "existence of a unit root" is rejected for each variable at a significance level of 1%. This indicates that all variables, including government subsidy (sub), enterprise risk (risk), and innovation performance (patent), are stationary at the first order, enabling the construction of a PVAR model.

Table 3. Unit Root Test Results

Variable	LLC		IPS		ADF-F		Result
	Statistics	P-value	Statistics	P-value	Statistics	P-value	
sub	-10.6940	0.000	-10.3153	0.000	262.4434	0.000	Stationary
risk	-19.4568	0.000	-4.7814	0.000	528.6759	0.000	Stationary
patent	-22.0381	0.000	-9.7757	0.000	447.7491	0.000	Stationary

Lag Order Determination.

In order to determine the optimal lag order for the PVAR model, it is necessary to consider the Consistent Moment and Model Selection Criteria proposed by Andrews and Lu [13]. Based on the results shown in Table 4, the first-order lag still meets the requirements for steady-state estimation and after several attempts, it was found that the first-order lag model yielded the best results. Therefore, this study sets the lag order of the PVAR model to the first order.

Table 4. Lag Order Determination

Lag Order	CD-value	J-value	P-value	MBIC	MAIC	MQIC
1	0.8625271	38.2589	0.0738607	-123.5106*	-15.7411	-58.41923*
2	0.862241	16.34092	0.5687677	-91.50544	-19.65908*	-48.11117
3	0.8794745	7.885422	0.545733	-46.03776	-10.11458	-24.34062

Note: * denotes the minimum value for the lag order.

Estimating Vector Autoregressions.

The GMM Estimation results of the study's PVAR Model is as shown in Table 5.

Table 5. GMM Estimation Results of PVAR Model

Variable	h_sub	h_risk	h_patent
L.h_sub	1.130***	-0.0175	-0.591***
	(3.25)	(-0.03)	(-2.87)
L.h_risk	0.0522	0.654***	-0.0589***
	(1.48)	(12.36)	(-2.79)
L.h_patent	0.243*	-0.231	0.212**
	(1.80)	(-1.19)	(2.42)

Note: * indicates p<0.1, ** indicates p<0.05, *** indicates p<0.01.

In the second column of Table 5, government subsidies are taken as the dependent variable. The results indicate that corporate risk-taking in the previous period has a weak effect on promoting government subsidies. However, government subsidies and previous innovation performance significantly promote current government subsidies. This implies that current government subsidies for enterprises are influenced by past subsidies and the level of innovation performance. In other words, a track record of successful innovation can help companies secure more government subsidies.

In the third column of Table 5, corporate risk-taking is the dependent variable. The results reveal that government subsidies in the previous period have a weak inhibitory effect on corporate risk-taking in the current period. This could be attributed to the rent-seeking costs associated with government subsidies, which may crowd out internal innovation resources and distort the allocation of subsidy resources.

In the fourth column of Table 5, innovation performance is the dependent variable. The results indicate that government subsidies in the previous period have a significant inhibitory effect on current innovation performance. Additionally, corporate risk-taking in the previous period also significantly inhibits current innovation performance. This may be due to companies neglecting risk assessment and the enhancement of their own capabilities, blindly pursuing increased risk-taking. As a result, there is a growing mismatch between corporate innovation capabilities and risk-taking abilities, making it difficult for companies to effectively utilize their resources and develop new products, ultimately hampering innovation performance.

Impulse Response Analysis.

Due to the presence of numerous regression coefficients in the PVAR model, it becomes challenging to explain the continuous interrelationships among variables in the future. Therefore, the impulse response graph is utilized to visually illustrate the interactive relationships among variables over the next six periods. The results of the impulse response analysis are depicted in Figure 1 (Figs. 1a, 2a, 3a, etc. in Fig. 1).

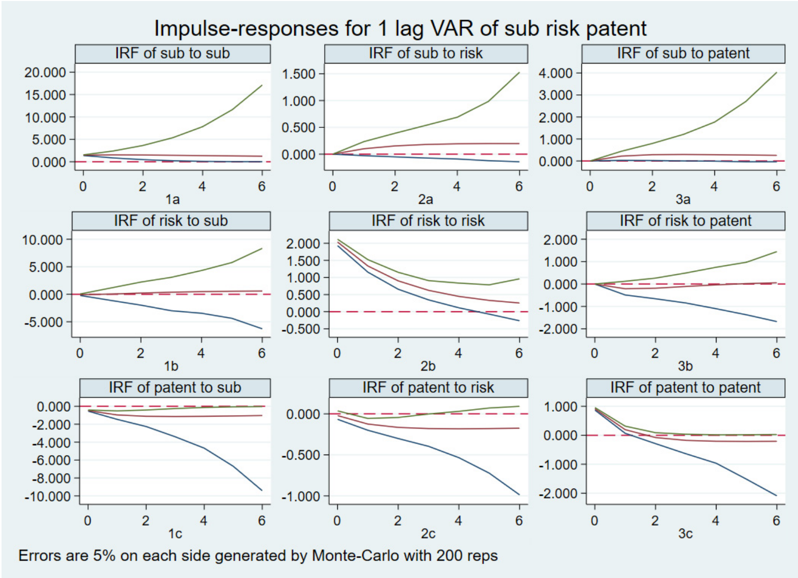

Fig. 1. Impulse Response Graph

First, let's examine the three graphs on the diagonal, which represent the influence of government subsidies, corporate risk-taking, and innovation performance on themselves. From the graphs, it can be seen that all three variables have a positive influence on their own future, with the first period showing the most significant positive impact. The impact of corporate risk-taking is higher than that of government subsidies, and the impact of government subsidies is higher than that of innovation performance. However, the positive impact of these variables gradually decreases over time, with government subsidies and corporate risk-taking diminishing by approximately the sixth period, while innovation performance has a negative impact starting from the second period and tends to stabilize.

Next, let's analyze the impact of government subsidies on corporate risk-taking and vice versa. The influence of government subsidies on corporate risk-taking is not evident in the current period, and overall, it has a very weak effect, showing almost no significant impact (Figure 1b). On the other hand, there is a significant lag period between corporate risk-taking and government subsidies, with the highest promotion observed in the second period, followed by a gradual stabilization (Figure 2a).

Moving on to the impact of government subsidies on innovation performance and vice versa, government subsidies have a negative impact on innovation performance in the current period, reaching its highest negative level in the first period and stabilizing thereafter (Figure 3a). On the other hand, there is a significant positive effect of innovation performance on government subsidies from the end of the period to the fifth period, which tends to stabilize (Figure 3a).

Furthermore, corporate risk-taking has a significant negative impact on innovation performance in the first period, reaching its maximum response value in the third period and then gradually stabilizing (Figure 2c). Conversely, innovation performance has a negative impact on corporate risk-taking in the first period, gradually converging to zero by the fourth period (Figure 3b). These impulse response results validate the findings of the PVAR model over a longer time horizon.

Variance Decomposition.

The results of the variance decomposition for six different observation periods (5th, 10th, 15th, 20th, 25th, and 30th periods) are presented in Table 6.

Table 6. Variance Decomposition Results

	s	sub	risk	patent
sub	5	0.963	0.009	0.027
risk	5	0.054	0.934	0.012
patent	5	0.823	0.018	0.159
sub	10	0.952	0.016	0.032
risk	10	0.216	0.771	0.012
patent	10	0.875	0.022	0.103
sub	15	0.948	0.018	0.034
risk	15	0.313	0.672	0.015
patent	15	0.888	0.024	0.088
sub	20	0.947	0.019	0.034
risk	20	0.364	0.618	0.017
patent	20	0.894	0.024	0.081
sub	25	0.946	0.02	0.034
risk	25	0.393	0.589	0.018
patent	25	0.897	0.025	0.078
sub	30	0.945	0.02	0.035
risk	30	0.41	0.571	0.019

Regarding the contribution of other variables to innovation performance, government subsidies have a significant impact and their contribution increases as the number of periods increases. In the 5th period, government subsidies account for 82.3% of the variance in innovation performance, while in the 30th period, this contribution rises to 89.9%. This highlights the importance of government subsidies in promoting innovation performance. The effect of innovation performance to government subsidies and corporate risk-taking gradually increases over different periods. This suggests that the impact of innovation performance on other variables is long-term, which aligns with the findings from the impulse response analysis. Furthermore, in addition, government subsidies play a significant role in influencing corporate risk-taking. In the 30th period, government subsidies contribute 41% to the variance in corporate risk-taking, indicating that the appropriate allocation and distribution of government subsidies can enhance the level of corporate risk-taking.

Granger Causality Test.

To test this, the Granger causality test is conducted on the relevant variables (refer to Table 7). The null hypothesis of the Granger causality test states that the variable is not a Granger cause of the explained variable. If the calculated P-value is less than 0.05, the null hypothesis is rejected, indicating that the variable is indeed a Granger cause of the explained variable.

Table 7. Granger Causality Test Results

Variable	Null hypothesis	$\chi 2$	df	P-value
sub	risk is not the cause	2.192	1	0.139
	patent is not the cause	3.2411	1	0.072
	neither risk nor patent is the cause	4.9657	2	0.084
risk	sub is not the cause	0.00116	1	0.973
	patent is not the cause	1.4255	1	0.233
	neither sub nor patent is the cause	2.7311	2	0.255
patent	sub is not the cause	8.2091	1	0.004
	risk is not the cause	7.8004	1	0.005
	neither sub nor risk is the cause	11.949	2	0.003

Looking at Table 7, both government subsidies and corporate risk-taking are identified as Granger causes of innovation performance, indicating that the levels of government subsidies and corporate risk-taking can influence the development of innovation performance. However, government subsidies and innovation performance are not identified as Granger causes of corporate risk-taking, suggesting that their immediate impact on corporate risk-taking is not significant. Similarly, neither corporate risk-taking nor innovation performance is identified as the Granger cause of government subsidies, implying that their short-term role in promoting government subsidies is not apparent.

4 Conclusions

4.1 Research conclusion

This study focused on listed companies in the pharmaceutical manufacturing industry and utilized the PVAR model, impulse response function, and variance decomposition analysis methods to examine the dynamic interactions among government subsidies, corporate risk-taking, and innovation performance. The findings of this study can be summarized as follows: (1) Corporate risk-taking plays a significant role in promoting government subsidies, contributing to a certain extent. However, the impact of government subsidies on corporate risk-taking is relatively weak. (2) Government subsidies have a restraining effect on innovation performance, contributing to a certain extent. On the other hand, innovation performance significantly promotes government subsidies, albeit with a lower contribution rate compared to the former. (3) Corporate risk-taking negatively affects innovation performance, with a certain contribution rate. Conversely, innovation performance has a weaker inhibitory effect on corporate risk-taking.

4.2 Suggestions

The research findings have several implications for both policymakers and industry practitioners in the pharmaceutical manufacturing sector. (1) They should for risk prevention and resourcing in the context of its own realities, maintain confidence in long-term innovation endeavors, formulate strategies that promote innovation-driven development, and ensure sufficient resource support throughout the research and development process. (2) Enterprises should reasonably change their Assumption of risk capacity. It is essential to note that the bearing limits for each risk enterprises take will vary based on the company size, financial position, and risk appetite. Therefore, it is crucial for enterprises to conduct their risk assessments, engage with risk management experts, and consider their unique circumstances when setting bearing limits for different types of risks. (3) Policymakers should strive to avoid implementing "one size fits all" subsidy policies. Instead, they should tailor subsidy conditions to the specific circumstances of enterprises. This approach prevents companies from blindly conforming to subsidy conditions that may not align with their actual needs and minimizes the negative impact of enterprises disregarding market demand.

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