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Drug Procurement, R&D Models, and Innovation Performance of Pharmaceutical Companies

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Abstract: Under the multi-objective public policy of national centralized banded purchasing of medicines ("Drug Procurement"), winning pharmaceutical companies are faced with the dual dilemma of declining product profits and high investment in innovation. Although the centralized drug procurement policy significantly reduces drug prices and alleviates the burden of patients, the mechanism of its impact on the innovation performance of pharmaceutical companies is still unclear, and an in-depth study of this mechanism can help to comprehensively understand the effect of the implementation of the centralized drug procurement policy. By constructing a multi-period double-difference model to investigate the impact of the drug collection policy on the innovation activities of enterprises, the study finds that the drug collection policy significantly improves the innovation performance of selected enterprises through two paths, namely internal R&D and external cooperation. Heterogeneity analysis shows that the drug collection policy significantly enhances the innovation performance of larger enterprises and pharmaceutical enterprises whose leading products are chemicals, and has a more significant positive effect on the innovation performance of state-owned enterprises compared with that of non-state-owned enterprises. On the basis of empirical analysis, suggestions are made for policy improvement.

Keywords: Centralized Drug Procurement, Pharmaceutical Companies, R&D Model.

1. Introduction

The centralized band purchasing of medicines (hereinafter referred to as "drug procurement") policy is a typical multi-objective major system innovation, which needs to maintain the synergistic development of "health insurance, medical care and pharmaceuticals", and the innovation ability of pharmaceutical enterprises directly affects the quality and level of medical services and is the basis of the ability to guarantee the sustainability of drug supply and cost control [1,2]. In this tripartite relationship, the innovation capacity of pharmaceutical companies directly affects the quality and level of medical services, and is also the basis of the ability to ensure the sustainability of the supply of medicines and the effect of cost control [1,2]. Existing literature mainly focuses on social hotspot issues, focusing on the aspects of suppressing drug prices and improving the efficiency of health insurance funds to evaluate the policy effect of drug collection and less attention is paid to its influence mechanism on the innovation performance of pharmaceutical enterprises [1,3,4]. Statistics show that since 2018, the state through the organization and implementation of drug collection and procurement policy, has accumulated more than 500 billion yuan for patients to reduce the burden, the average reduction in the price of the winning drugs by more than 50%. However, the effect of cost control based only on the "quantity for price" does not fully reflect the ultimate purpose of drug collection as a strategic procurement policy [3], and the long-term goal of the policy is to realize value-based healthcare by guiding the innovation and transformation of pharmaceutical enterprises [5].

There are still obvious theoretical differences among existing studies on how drug procurement, as a major exogenous shock, affects the innovation performance of pharmaceutical enterprises [5,6]. First, it is still controversial whether drug procurement positively or negatively affects the innovation performance of pharmaceutical enterprises. Previous studies have shown that, on the one hand, centralized drug procurement can change the long-standing phenomenon of "focusing on marketing, not on research and development" in the pharmaceutical industry, prompting enterprises to strengthen R&D investment, and return to innovation and quality competition [1,7,8], but on the other hand, it may also exacerbate the price competition, which may make the enterprise managers show more obvious short-sightedness and risk aversion tendency, thus reducing high-risk product innovation performance [5,6]. tendency, thus reducing high-risk product development activities [6]. Second, the existing literature lacks an in-depth discussion on how drug procurement affects the organization of R&D activities in pharmaceutical companies. Innovation chain research emphasizes that the traditional linear innovation model can no longer adapt to the iterative development speed of the technology market, and the enterprise innovation process needs to break through the organizational boundaries to achieve complementary resources and capabilities among multiple subjects in the innovation chain [9,10]. In such a background, the research interest of academics on innovation policy evaluation has gradually shifted from the traditional R&D input and output additionality to behavioral additionality, and more and more attention has been paid to evaluating the policy effect based on the organizational form of R&D activities, especially the inter-organizational R&D cooperation behavior [11,12]. Pharmaceutical manufacturing is a typical knowledge-intensive industry with high complexity of knowledge base, long R&D cycle, and high risk, and realizing value co-creation along the whole chain has become an inevitable path to gain sustainable competitive advantage [13,14]. Therefore, without an in-depth analysis of the relationship between its impact on the internal and external collaborative R&D model of the enterprise, it is difficult to clearly reveal the intrinsic mechanism of drug

collection and procurement affecting the innovation performance of pharmaceutical enterprises. Third, most of the existing literature on the evaluation of the effect of drug collection policy is based on the analysis of the industry as a whole or the exploration of typical cases [4], and the research conclusions formed are not consistent. Heterogeneity analysis based on different dimensions, such as enterprise size, product category and ownership form, helps to present more clearly the relationship between the impact of drug collection on the innovation performance of pharmaceutical enterprises.

In order to outline the above issues, the implementation of the drug collection policy is regarded as a quasi-natural experiment, and a multi-period DID model is constructed for empirical analysis by combining the enterprise-level data of listed pharmaceutical companies. Selecting in-house R&D and cooperative R&D as intermediate variables, and based on the type of partners, further subdividing the cooperative R&D mode into three types of upstream suppliers, customer organizations and research institutes in the study, we explore the impact path of the drug collection on the innovation performance of the selected enterprises, and at the same time, we conduct a heterogeneity analysis based on the three dimensions of enterprise size, product type and ownership structure, so as to more completely We also analyze the heterogeneity based on enterprise size, product type and ownership structure, so as to present a more complete picture of the influence mechanism of drug collection policy on the innovation performance of enterprises.

2. Research Design

2.1. Research Hypothesis

2.1.1. Drug Procurement and Innovation Performance of Pharmaceutical Companies

Pharmaceutical manufacturing industry is a typical innovation-driven manufacturing industry, which theoretically should rely on R&D and product innovation to obtain high profits [4,7]. However, China's pharmaceutical sales market for a long time there are too many drug circulation links, as well as public hospitals occupy the bilateral monopoly position of the buyer and seller market and other industry specificities, so that the “sales with gold” model prevails, pharmaceutical companies will be 30% to 70% of the sales revenue used for the market to seek rents, which greatly compressed the enterprise's market profit and R&D investment [7,15]. The imbalance of resource allocation in pharmaceutical enterprises affects their innovation ability and sustainable competitiveness. The prominent feature of drug collection and procurement is that health insurance enters the pharmaceutical market as a strategic buyer, which changes the pharmaceutical market from a two-party game between hospitals and pharmaceutical enterprises to a three-party game [1]. As a major institutional innovation that affects the ecology of the whole industry, the drug collection policy will inevitably affect the strategic transformation and resource allocation strategy of pharmaceutical enterprises [6].

Drug procurement may enhance the innovation performance of pharmaceutical enterprises through the positive guiding role of strategic purchasers and the forcing effect brought by market competition. On the one hand, drug procurement increases customer concentration, which is conducive to the role of health insurance as a strategic buyer to guide pharmaceutical firms in product innovation. Resource dependence theory suggests that the increase in customer concentration increases the switching cost of the enterprise, prompting the enterprise relationship by increasing customer-oriented dedicated investment and R&D activities as a defensive strategy to maintain customer relationships [16]. At the same time, drug collection as a demand-side policy tool can weaken the “free-rider” problem and uncertainty risk of innovation behavior, prompting the winning enterprises to shift their strategic focus from sales to product innovation [1,8,15,17]. On the other hand, through consistency evaluation and controlling the number of winning enterprises, drug collection and procurement excludes low-end competitors, avoids the problem of adverse selection caused by the lemon market effect, and is conducive to forcing enterprises to carry out technological innovation through the construction of a benign competition mechanism [18]. Based on the above analysis, hypothesis 1 is proposed:

Hypothesis 1: The drug collection policy positively affects the innovation performance of winning pharmaceutical companies.

2.1.2. Mediating Effects of R&D Models

Existing studies usually distinguish the innovation behavior of enterprises into two R&D modes: internal R&D and collaborative R&D. For a knowledge-intensive industry such as pharmaceutical manufacturing, how to integrate the internal and external innovation resources of the organization through internal R&D and collaborative R&D has become a key issue in the strategic decision-making of organizational innovation [19-21].

Facing the major change of drug collection policy, pharmaceutical enterprises usually prioritize to promote technological innovation by increasing internal R&D investment, mainly based on the following three reasons. First of all, the innovation process of pharmaceutical manufacturing industry has strong knowledge accumulation, high innovation exclusivity but high innovation risk and low success rate, and this unique technology system of pharmaceutical industry determines the importance of internal R&D [22]. Secondly, the “quantity for price” method of drug collection guarantees the expected income of the selected enterprises, which enhances the willingness to increase internal R&D investment. The selected enterprises can obtain 60%-70% of the sales volume in the target market, and the increase in market share, the decrease in selling expenses, and the faster settlement rate of medical insurance have enhanced the enthusiasm of pharmaceutical enterprises to carry out in-house R&D activities [1,5,15,23]. Third, due to the imperfect development of China's financial market, the cost of obtaining external financing is high for enterprises, and government purchase orders can play a signaling effect and a collateral effect to alleviate the financing constraints for enterprises to carry out R&D activities [15]. Based on the above analysis, hypothesis 2 is proposed:

Hypothesis 2: The drug collection policy prompts winning firms to improve their innovation performance through internal R&D investment.

On the other hand, pharmaceutical R&D is technically complex and risky, and the knowledge base required in the R&D process is widely dispersed among different types of organizations [24]. It has been shown that pharmaceutical companies will adapt to changes in the competitive environment brought about by external shocks by selecting and adjusting the type of collaborative R&D partners [25]. Therefore, the drug collection policy will inevitably affect the

R&D cooperation mode of pharmaceutical enterprises across organizational boundaries, which in turn will have an impact on the innovation performance of the enterprises.

Based on the following two reasons, drug collection creates favorable conditions for selected enterprises to enhance innovation performance through cooperative R&D. First, drug collection makes the selected enterprises have stable market returns and alleviates the financing constraints in the development process, stimulates the development motivation of the selected enterprises to pursue economies of scale and scope, and enhances the enterprises' willingness and ability to integrate innovative resources across organizations through R&D cooperation [26-28]. Second, drug procurement plays a signaling role to reduce the uncertainty risk of conducting collaborative R&D among organizations. Uncertainty risk is one of the most important barriers affecting inter-organizational collaborative R&D, and government procurement can play a signaling effect and a collateral effect to send positive signals to the market and potential partners about firms' innovation capabilities and technological advantages [15,28], thus promoting inter-organizational collaborative innovation. Based on the above analysis, hypothesis 3 is proposed:

Hypothesis 3: The drug collection policy can improve innovation performance by enhancing collaborative R&D of winning firms.

2.2. Research Methodology

2.2.1. Description of Measurement Models and Variables

In this paper, the implementation of the drug collection policy is regarded as a quasi-natural experiment, and the following fixed effects model is constructed using the multi-period DID model for empirical testing:

$$Y_{it} = \alpha_0 + \alpha_1(Treat_i \times \text{Period}_{it}) + \sum_k \alpha_k X_{it} + \mu_{it} + \varphi_{it} + \varepsilon_{it}. \quad (1)$$

With reference to previous studies, this paper adopts the number of invention patent applications to measure the innovation performance of enterprises, and in order to avoid the influence of too discrete explanatory variables on the research results, this paper takes the logarithmic value of the number of invention patent applications after adding 1 to the number of invention patent applications. Pharmaceutical manufacturing industry innovation exclusivity is high, the enterprise tends to protect the innovation achievements by applying for patents, taking into account the existence of a certain lag in patent authorization, the number of invention patent applications can be a more realistic response to the innovation performance of pharmaceutical enterprises [22,29].

The core explanatory variable is a dummy variable indicating a policy shock variable that varies with the drug collection policy and the time of implementation, with a value of 1 indicating that firm i was the winning firm in the drug collection in year t, and a value of 0 indicating that it was not. Treat is a variable that distinguishes between the experimental group and the control group, with a value of 1 indicating that firm i was the winning firm in the drug collection, and 0 otherwise. period is a time dummy variable for the drug collection policy, the year in which the policy was formally implemented takes the value of 1, otherwise 0. It is a series of control variables; and is a province and year fixed effect; and is a random disturbance term. Period is a time dummy variable for the drug collection policy, i.e., the year in which the policy began to be formally implemented takes the value of 1, otherwise it is 0. It is a series of control variables; and is province and year fixed effects; and is a random perturbation term.

Since the causal relationship of the mediating variables to the explanatory variables is clearer, in order to test the mediating effect of the R&D model, we refer to the practice of Jiang Ting scholars [30] and Huang Xianhai scholars [31], focusing on the relationship of the explanatory variables to the influence of the mediating variables. Therefore, model 2 is constructed on the basis of model 1 to test the mediating effect:

$$Med_{it} = \beta_0 + \beta_1(Treat_i \times \text{Period}_{it}) + \sum_k \beta_K X_{it} + \mu_{it} + \varphi_{it} + \sigma_{it}. \quad (2)$$

The mediating variables include internal R&D and collaborative R&D. In-house R&D is measured using the ratio of the firm's technical staff to the firm's total number of employees, and collaborative R&D is measured using the logarithmic value of the number of joint patent applications filed by the pharmaceutical firm and its partners plus one.

The control variables in the above two regression equations include: gearing ratio (the proportion of total liabilities and total assets), firm size (the natural logarithm of total assets), firm growth rate (the annual growth rate of firms' operating revenues), Tobin Q value, the size of the board of directors, equity concentration (the proportion of shares held by the first largest shareholder), management shareholding (the number of shares held by the management divided by the total capital stock), the combination of two positions (the chairman and the general manager is the same person as l, otherwise 0), nature of property rights (the nature of state-owned property rights, take 1, otherwise 0), institutional shareholding ratio (total number of shares held by institutional investors / outstanding share capital).

2.2.2. Data Sources

This paper takes the A-share listed companies of pharmaceutical enterprises from 2015 to 2022 as the research sample, and excludes the samples of companies with ST, *ST, and PT, and also excludes the companies listed in 2018 and after 2018 in order to avoid the impact of the observation window being too short on the estimation results. Considering that the current national drug collection has been carried out in 9 rounds, of which the 9th round has not yet been landed and implemented, and the winning results of the 7th round will be landed and implemented in July 2022, which is still less than one fiscal year, the domestic listed enterprises that have won the bidding in the previous 6 rounds are used as the experimental group. In the end, 140 sample enterprises were obtained, including 31 in the experimental group and 109 in the control group, totaling 1,120 annual observations. The relevant data of the sample enterprises (including the number of patent applications) are obtained from the CSMAR database; the relevant data of the drug collection and procurement are manually organized based on the reports of Shanghai Sunshine Pharmaceutical Purchasing Network and other relevant websites; the information of joint patent applications between enterprises used to construct the R&D

cooperation variables is obtained from the database of Wisdom Sprout (PatSnap).

3. Empirical Analysis

3.1. Regression to Baseline

The results of the benchmark regression are shown in Table 1. In column (1) only the main explanatory variables are entered into the regression equation, and columns (2) through (4) gradually put the control variables, year fixed effects and province fixed effects into the regression equation. From the estimation results in column (4), it can be seen that after adding the time and province fixed effects as well as each control variable, the regression coefficient of the dummy variable did for participation in centralized banded purchasing is 0.18 and passes the test at the 5% significance level, which indicates that participation in the national centralized banded purchasing policy for pharmaceuticals increases the number of invention patents of pharmaceutical enterprises and enhances the level of breakthrough innovation of enterprises, and the research hypothesis H1 is established.

Table 1. Baseline Estimated results

	(1)	(2)	(3)	(4)
Treat×Period	0.18*	0.11	0.24***	0.18**
	(0.10)	(0.09)	(0.09)	(0.09)
Constant	2.43***	-6.52***	-6.75***	-6.50***
	(0.03)	(0.97)	(0.95)	(0.99)
Control Variable	NO	YES	YES	YES
Year FE	NO	NO	YES	YES
Province FE	NO	NO	NO	YES
Observations	1,120	1,086	1,086	1,086
R-squared	0.01	0.21	0.25	0.33

Note: *** p<0.01, ** p<0.05, * p<0.1; robust standard errors in parentheses, below.

3.2. Applicability Test of the Difference-in-Differences Method

3.2.1. Parallel Trend Test

One of the core assumptions of the double-difference model is that the experimental group and the control group need to satisfy the parallel trend before the implementation of the policy, i.e., before the policy is introduced, the explanatory variables of the two groups should have similar temporal trends. In multi-period DID modeling, it is especially critical to test the "parallel trend" assumption. A common approach is to introduce an interaction term between the time dummy and the policy variable in the regression analysis. If the interaction term is not significant before the policy is implemented but is significant after the policy is implemented, the hypothesis of parallel trends between the experimental and control groups is satisfied.

For the incentive effect of the centralized band purchasing policy for drugs, this paper uses a 90% confidence interval to show the results of the parallel trend test. As shown in Figure 1, before the implementation of the policy, the confidence interval intersects the 0 axis, indicating that the coefficients before the implementation of the policy cannot reject the hypothesis of equal to 0 within the 90% confidence interval; and after the implementation of the policy, the confidence interval no longer intersects the 0 axis, indicating that the policy has a significant incentive effect on the innovation performance of pharmaceutical enterprises. Therefore, it can be determined that there is no significant difference between the experimental group and the control group before the implementation of the policy, and there is a significant difference after the implementation of the policy, and the parallel trend hypothesis is established.

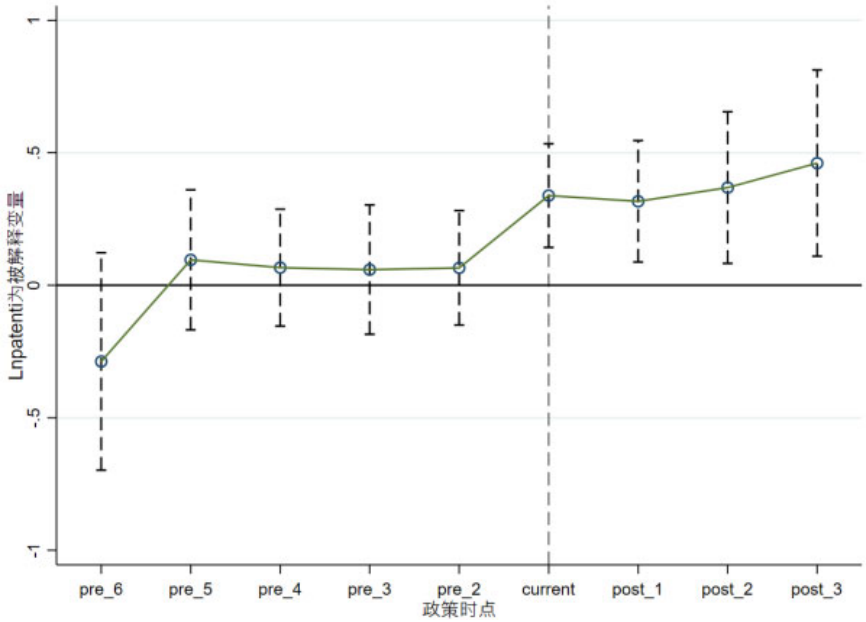

Figure 1. Parallel Trend Test Chart

3.2.2. Placebo Test

In order to test the extent to which the above empirical results are affected by omitted variables, random factors, etc., we construct a set of randomized experiments containing two dimensions: randomized winning firms and randomized implementation time, by randomly "screening" winning firms under the collection policy and randomly generating the policy implementation time. In this paper, we construct a virtual experimental group to make the impact of drug collection on winning companies become random, regress according to the multi-period double-difference benchmark regression model containing control variables, and repeat this process 500 times. The results in Figure 2 show that the regression coefficients fall around the value of 0 and follow a normal distribution, with the majority of regressions being insignificant. The coefficient estimates in the benchmark regression are located in the high tail of the distribution of spurious regression coefficients, which are small probability events in the individual placebo test. Accordingly, it can be ruled out that the benchmark estimates in this paper are due to unobservable factors.

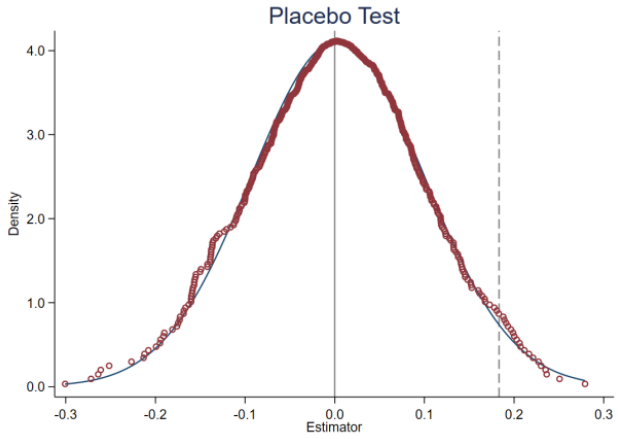

Figure 2. Placebo Test Chart

3.3. Robustness Check

3.3.1. PSM-DID Test

In order to screen the control group more accurately, this study draws on the practice of Lu Shengfeng et al. (2021) [32] and adopts the Propensity Score Matching (PSM) method in order to test the causality of the centralized band purchasing policy on the innovation performance of pharmaceutical companies. After incorporating the same control variables as in the baseline regression, this study constructed a Logit model-based policy impact variable (Treat) for determining whether enterprises are affected by the centralized band purchasing policy. The firms' propensity scores were calculated based on the predicted probability (P-value) of the model, and the experimental and control groups were matched in a 1:1 ratio using the nearest-neighbor matching method to improve the robustness of causal inference. Table 2 demonstrates the results of the propensity score matching (PSM-DID) regression, and the data show that after eliminating the sample selectivity bias, winning the centralized procurement of pharmaceuticals has a positive effect on innovation performance at the 5% significance level. This result further supports the empirical findings of this paper.

3.3.2. Other Robustness Tests

In order to verify the robustness of the impact of the centralized band purchasing policy on the innovation performance of pharmaceutical listed enterprises, this paper conducted tests from several angles, and the results are shown in Table 2. First, with reference to Tang Yunshu (2023), the explanatory variable is replaced from the number of invention patent applications to the number of invention patents independently obtained by enterprises in the year, and the regression results show that the estimated coefficient of the double-difference interaction term Treat×Period is 0.217, which is significantly positive at the 5% significance level, indicating that the policy's promotional effect on the enterprises' innovation performance is robust. Second, the observation window is adjusted to 2016-2022 in order to exclude the possible interference of historical policies, such as the Notice on Implementing the Guidance on Improving the Centralized Procurement of Drugs in Public Hospitals issued by the National Health and Planning Commission in 2015, on the findings of the study. The adjusted regression results show that the estimated coefficient of Treat×Period is 0.186, which is significantly positive at the 5% significance level, further validating the robustness of the policy effect. In addition, considering the long R&D cycle of enterprises, the number of invention patent applications in one period in advance is used as the explanatory variable for the test, and the results show that the estimated coefficient of Treat×Period is 0.219, which is significantly positive at the 10% significance level, indicating that the policy promotion effect is still robust. In summary, the robustness test results consistently support the positive impact of the centralized band purchasing policy on the innovation performance of pharmaceutical enterprises.

Table 2. Baseline Estimated results

	PSM—DID	Substitut-ion of explanato-ry variables	Observa-tion window adjustme-nt	Explained variables one period ahead
Treat×Period	0.19**	0.22**	0.19**	0.22*
	0.09	(0.09)	(0.09)	(0.13)
Constant	-6.87***	-6.50***	-5.70***	-5.95***
	(1.02)	(0.94)	(1.05)	(1.26)
Observations	1013	982	954	679
R-squared	0.35	0.31	0.34	0.32
Control Variable	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Province FE	YES	YES	YES	YES

3.4. Impact Path Analysis

The regression results are shown in Table 3, the core explanatory variable Treat×Period has a significant positive effect on both internal R&D and collaborative R&D, indicating that the selected enterprises in the drug collection enhance their innovation performance by increasing internal R&D and external collaboration, and hypotheses H2 and H3 have passed the empirical test.

Previous literature has suggested, based on the knowledge base view, that different types of collaborative R&D partners in the innovation chain, such as suppliers, customers, and universities and public research institutions, possess heterogeneous innovation resources, and thus the choice of R&D partners represents a dynamic adaptation process of firms to cope with environmental changes in the presence of exogenous shocks, and is one of the most important strategic decisions for firms [33 -35]. Therefore, this paper conducts a more in-depth analysis of the impact mechanism by distinguishing three types of R&D partners: supplier firms, users (hospitals), and public research institutions such as universities.

The regression results on the right side of Table 3 show that the core explanatory variable Treat × Period has a significant positive effect on R&D cooperation with upstream suppliers, and the coefficients of the effect on downstream customers and horizontal R&D cooperation are positive but not significant. It can be seen that under the influence of the drug collection policy, pharmaceutical companies mainly enhance their innovation performance by strengthening R&D cooperation with raw material suppliers. The possible reason is that the collaborative innovation between enterprises and users, universities and research institutes helps to accurately identify market demand, acquire diverse knowledge and cutting-edge technologies, respectively, which is conducive to the realization of breakthrough innovations [36,37], whereas the cooperation with suppliers is more inclined to DUI (The learning-by-doing, by-using and by- interacting) innovation model, which focuses on the accumulation of knowledge of existing technology paths, and thus can accelerate the speed of innovation, reduce R&D costs and innovation risks [38].

Obviously, the results of this study are noteworthy in that the traditional linear development model is difficult to adapt to the current complex value chain and fierce market competition environment, and technological innovations in high-technology fields are becoming increasingly dynamic and chained [39,40], and thus the diversification of technological sources and partners has become a key factor influencing the innovation performance of firms [41]. However, realizing the potential of alliances takes time, including coordinating partners and internalizing knowledge into routines and resource bases [13]. Therefore, how to build an innovation ecosystem has become an important challenge for pharmaceutical companies in China.

Table 3. Results of the Analysis of Impact Mechanisms

	R&D Model		**Type of collaborative R&D**		
	Intern-al R&D	Collaborative R&D	Provide-r	Subscri-bers	Resear-ch institu-tion
	1	2	3	4	5
Treat×Period	0.03**	0.24***	0.18**	0.02	0.04
	(0.01)	(0.08)	(0.07)	(0.04)	(0.05)
Constant	0.16	-2.58***	-1.02***	-1.05***	-1.03***
	(0.13)	(0.58)	(0.39)	(0.31)	(0.39)
Observations	1,086	1,086	1,086	1,086	1,086
R-squared	0.33	0.17	0.11	0.10	0.11
Control Variable	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES

3.5. Heterogeneity Analysis

This paper groups the sample enterprises based on main business revenue, product category and whether the actual controller is a state-owned enterprise respectively, and analyzes the heterogeneity from three aspects: enterprise size, product type and ownership structure. The results of the study are shown in Table 4, which shows that the drug collection policy has significantly different impact relationships on different types of enterprises. There is a significant positive impact of the drug collection policy on the larger-scale enterprises, while the impact on the smaller-scale enterprises is not significant, there is a significant positive impact on the chemical drug enterprises, while there is no significant impact on the biopharmaceutical enterprises, and there is a significant impact on the state-owned and non-state-owned two types of enterprises, but the impact on the state-owned enterprises is more significant.

From the perspective of enterprise size, the drug collection policy has a significant positive effect on the innovation performance of larger-scale enterprises, while for smaller-scale enterprises this effect is not significant. The regression results are similar to the results of previous studies [1], the possible reason is that large-scale pharmaceutical enterprises have strong financial and technological strength, as well as the advantage of product diversity, the drug collection has a limited impact on their total revenue and net profit, and they can quickly adjust the research and development investment in technological innovation activities under the impact of the drug collection [1], and the previous studies believe that small and medium-sized enterprises (SMEs), although more innovative, are limited by insufficient funds and capacity to carry out their innovative activities [1]. Previous studies have concluded that although SMEs are more innovative, their lack of capital and capacity limits their innovative activities [42], and due to the lack of strategic resources, it is particularly important for enterprises to acquire these resources through inter-organizational cooperation [26].

In terms of product type, drug procurement significantly enhances the innovation performance of firms interested in chemical drugs, while there is no significant effect on

biological products, which is also noteworthy. Drug procurement squeezes the profit margins of generic drugs, prompting these firms to transform into innovative firms, but such firms tend to be chemical drug firms [4]; developing new products in the biopharmaceutical industry is also highly strategic, but the difficulty of development, complex and expanding knowledge base, and widely dispersed sources of expertise are features that raise the threshold and risk of innovation [14], and thus how to promote innovation in the biopharmaceutical field is also an important challenge.

In terms of ownership structure, there is a significant impact on both state-owned and non-state-owned enterprises, but the impact on state-owned enterprises is more significant. Previous studies on the innovation activities of different types of ownership have more controversy, such as the existence of unclear property rights, proxy and other factors that impede the utilization of innovation resources in state-owned enterprises, but state-owned enterprises on the one hand tend to have stronger technical strength and knowledge accumulation, and enjoy policy support, business protection and more favorable bank loan conditions, thus having a more favorable external innovation environment [43,44]. In contrast, private enterprises can face market changes and make decisions faster, but are limited to institutional, technological and financial constraints, avoiding the high risk of innovation [1,44]. Therefore, it is also a question of how to break down the obstacle factors and stimulate the innovation enthusiasm of different ownership enterprises.

Table 4. Heterogeneity Analysis Regression Results

	Enterprise size		**Product Type**		**Ownership nature**	
	Larger	Smaller	Chemical	Biological	State-owned	Non-state-owned
Treat×Period	0.37***	0.03	0.23**	-0.02	0.49***	0.19*
	-0.12	-0.14	-0.11	-0.28	0.18	0.10
Constant	-9.63***	-6.53***	-13.09***	-9.22**	-9.53***	-6.41***
	-1.87	-1.80	-1.51	-3.74	2.15	1.15
Control Variable	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Observations	497	587	458	203	236	849
R-squared	0.36	0.34	0.55	0.47	0.57	0.32

4. Conclusions and Implications

4.1. Conclusion

The increased complexity of innovation has led to the failure of the traditional linear model, and the government's guidance of firms' innovation activities has increasingly emphasized the encouragement of inter-firm cooperation, although there is often an obvious gap between policy goals and practical effects [39]. This paper analyzes the impact mechanism of the drug collection policy on the innovation performance of pharmaceutical enterprises, which contributes to a more comprehensive understanding of the implementation effects and possible problems of multi-objective public policies such as drug collection, and makes suggestions for policy improvement [15,45]. In this paper, we introduce the theoretical perspectives of behavioral additionality and innovation chain, and select the R&D mode of enterprises as the mediating variable to explore the impact mechanism of drug collection policy on the innovation performance of pharmaceutical enterprises. The results of the study show that the drug collection policy significantly enhances the innovation performance of selected enterprises through both internal R&D and external cooperation; further analysis reveals that the drug collection policy mainly enhances the R&D cooperation between pharmaceutical enterprises and their suppliers, and does not significantly enhance the R&D cooperation between them and their users' organizations, as well as universities and public research institutes; and the analysis of heterogeneity shows that the drug collection policy significantly enhances the innovation performance of larger-scale enterprises and enterprises whose dominant products are chemical products. Heterogeneity analysis shows that the drug collection policy significantly improves the innovation performance of large-scale enterprises and pharmaceutical enterprises whose leading products are chemicals, although the drug collection policy has a significant positive effect on the innovation performance of both state-owned and non-state-owned enterprises, but the state-owned is more significant.

4.2. Policy Implications

Based on these conclusions, the paper makes the following recommendations:

First, in implementing the drug collection policy, more attention should be paid to balancing multiple policy objectives. In the tripartite relationship between health insurance, medical care and pharmaceuticals, the innovation capacity of pharmaceutical enterprises is a key factor in guaranteeing the quality of medical services and the efficiency of the use of health insurance funds. Therefore, the innovative transformation of pharmaceutical enterprises should be promoted as an important evaluation criterion of the drug procurement policy. Specific measures include providing incentives for innovation through financial subsidies and tax incentives, as well as strengthening policy transparency and stability in order to reduce enterprises' concerns about policy uncertainty.

Second, the innovation performance of pharmaceutical enterprises depends on the efficiency of resource integration and cooperation among multiple subjects along the entire innovation chain. Empirical studies show that the drug collection policy mainly promotes R&D cooperation between enterprises and suppliers, but the promotion of upstream and downstream innovation cooperation is still insufficient. Therefore, it is recommended to encourage pharmaceutical enterprises to establish joint R&D platforms or innovation alliances with downstream users such as universities, scientific research institutes and hospitals through special financial support and project guidance, so as to promote the transformation of basic research results into application

development. At the same time, the efficiency of cooperation can be enhanced through the establishment of information sharing platforms and intermediary organizations.

Thirdly, as there are differences in how different enterprises feel about and react to policies in terms of their behaviours, it is necessary to formulate a hierarchy of support policies to stimulate the innovation momentum of different types of enterprises. For example, for small and medium-sized enterprises, special innovation funds and research and development support policies can be provided to reduce financing costs; for biopharmaceutical enterprises, intellectual property protection and technology trading platforms can be established to stimulate greater investment in breakthrough innovations; and for non-State-owned enterprises, a level playing field can be optimized to reduce the implicit barriers in the implementation of the policy, so as to stimulate the innovation dynamics of diversified enterprises.

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