Chinese Pharmaceutical Volume-Based Procurement Policy – Analysis of the Impact on Market Performance

Li, Yinli

UNIVERSITÉ DE GENÈVE

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Chinese Pharmaceutical Volume-Based Procurement Policy Analysis of the Impact on Market Performance

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LI Yinli

(FCO 68403)

Dissertation Supervisor: Professor Harald Hau, University of Geneva

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Abstract

China's pharmaceutical policy is continually evolving, addressing the long-standing tradition in the Chinese medical industry of "supporting medical services through drug sales." During the procurement process, both buyers and pharmaceutical companies have artificially increased procurement costs to serve their own interests, resulting in persistently high drug prices. Some physicians prescribe medications with the goal of maximizing the benefits for hospitals and themselves, leading to a consistently high proportion of medication costs in overall medical expenses for patients.

This directly impacts overall healthcare costs, contributing to the problem of expensive medical care. In response to these issues, the state has been introducing relevant pharmaceutical policies aimed at severing the financial ties between hospitals and pharmaceutical companies, thus decoupling doctors' interests from those of drugs and pharmaceutical enterprises. The main goal is to resolve the significant public concern of "expensive medical care.".

Starting in 2018, China initiated reforms in the medical system across various stages of drug production, distribution, sales, and usage, continuously exploring and adopting new drug procurement models to control procurement costs. In January 2019, the state issued the "National Centralized Drug Procurement Pilot Scheme," implementing a pilot program for volume-based drug procurement in the "4+7" cities, which began to be gradually promoted nationwide in September 2019.

The centralized volume-based drug procurement aims to reduce the financial burden on patients while ensuring reasonable profits for enterprises. Savings in medical expenses are rewarded to medical institutions according to regulations, striving to make this reform beneficial for patients, pharmaceutical companies, and medical institutions alike (Chang, 2021). This policy completely transformed the way hospitals in pilot areas purchase medications and brought structural changes to pharmaceutical production companies. The implementation of this policy presents both opportunities and challenges

for the bidding enterprises. On one hand, successful bidders can quickly capture a significant market share, effectively avoiding issues in pharmaceutical product sales channels, while simultaneously reducing sales and channel costs (Liu, 2020).

In this paper, we aim to discuss the changes in the operational performance of different types of pharmaceutical companies following the introduction of the volume-based procurement policy. Our hypothesis is that the volume-based procurement policy may have a positive impact on the gross profit margins of pharmaceutical companies. The pharmaceutical companies in the specific 11 pilot cities will be set as our experimental group, while those outside of the pilot zone will serve as the control group. Additionally, we hypothesize that different types of companies within the experimental group will exhibit varied performances. For instance, the performance of companies in northern China may differ from those in southern China; the impact on pharmaceutical companies may differ from that on medical device companies; and high-tech enterprises may experience different effects compared to ordinary enterprises.

Key words: Volume-Based Procurement Policy; Gross Margin; North and South Area; Medicine and Medical Device Companies; High-Tech and Low-Tech Medical Company

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1. Background about the Medical System

Healthcare is a crucial public welfare issue faced by every nation, with medical expenditures constituting a significant portion of national fiscal spending. In China, the longstanding practice of "supporting medical services through drug sales" has shaped the healthcare landscape. In recent years, China's public health spending per capita has increased significantly, placing pressure of health insurance system. Consequently, the state has placed great emphasis on reforming centralized drug procurement. The system can reduce drug transaction costs and lower retail drug prices. combined efforts from the government and the market can prevent dysfunctional phenomena. Against this backdrop, the government has continued to make China's pharmaceutical system healthier by introducing pharmaceutical policies (Fu, 2021).

1.1. The Development Process of China's Pharmaceutical Policy

China's pharmaceutical policy has gone through seven different stages, which are briefly described below:

(1) Unified Purchasing and Marketing Stage (1949-1980):

From the establishment of the People's Republic of China to the mid-1980s, China exercised comprehensive control over all aspects of the drug production, distribution, sale and usage, gradually forming a three-tier pharmaceutical wholesale system (An et al., 2021). At that time, due to scare pharmaceutical resources, the government implemented unified control over medicines, and the government pharmaceutical company set a unified procurement models and prices.

Since medicines were produced and distributed exclusively by the government, pharmaceutical companies lacked incentive for research and innovation. The supply and distribution of drugs did not fully meet the needs of hospitals and patients. The misalignment with market dynamics lead to supply-demand imbalance. supply and demand.

(2) Self-Procurement Stage (1980-2000):

Following the reform and opening up, China's economic conditions improved, and the national pharmaceutical company loosened its control over the pharmaceutical industry. The prices of some medicines were jointly negotiated between hospitals and pharmaceutical companies, and many details of the process lacked transparency, resulting in an inflated price and exacerbating the issue of, “supporting medical services through drug sales.” In response, the government decided to introduce a centralized procurement policy.

(3) Centralized Procurement Establishment Phase (2000-2005):

China relied on intermediary bidding to determine medicine prices, allowing for a certain degree of price premium on drugs.

(4) Centralized Procurement Adjustment Phase (2006-2010):

China used an internet platform to establish a database of required drugs under the guidance of the government, listing drug names and codes. Pharmaceutical companies could bid on the platform.

(5) Medicine Sorting and Purchasing Stage (2010-2015):

On July 15, 2010, the former Ministry of Health promulgated the “Standard for Centralized Procurement of Medicines in Medical Institutions”. transitioning from local explorations to nationwide pilot programs and gradually improving the system (Huang & Tao, 2020). The government introduced new policies to classify all medicines into essential and non-essential categories, with separate tenders for each.

(6) Medical Consortium Procurement Phase (2015-2018):

In May 2015, the National Development and Reform Commission, the National Health and Family Planning Commission, the Ministry of Human Resources and Social Security, and six other departments jointly issued the “Opinions on Promoting Drug Price

Reform", abolishing the government pricing system that had been in place for nearly 20 years (Zhu et al., 2019). Starting June 1st, 2015, most of the drug prices were mainly determined by the market. It aimed to gradually establish a market-led drug pricing mechanism, minimizing direct government intervention in medicine prices. (Shang et al., 2019). Separate bidding for essential and non-essential medicines was canceled. Drugs were obtained from provincial centralized procurement platforms. Multiple medical institutions were encouraged to work together to form a purchasing alliance to reduce pharmaceutical prices through bulk procurement.

(7) National Centralized Procurement Stage (2018- Present):

After 2018, the state established the National Healthcare Security Administration to formulate medical procurement policies. They initiated "'4 + 7' Volume-Based Procurement Policy", a pilot program in 11 cities aiming to reduce drug prices, save health insurance funds, and reduce the financial burden on patients. At the same time, it had a significant impact on medical institutions, pharmaceutical companies and patients (Shu et al., 2019).

In December 2018, the government announced the winning bid prices for drugs. Price reduction exceeded expectation. Supply and distribution became more transparent, further reducing financial burden on patients (Tan & Fan, 2019). The second and third batches of volume-based drug procurement were conducted in 2019 and 2020, expanding the variety of drugs, broadening the coverage, and refining the rules. Social acceptance steadily increased, moving. China's volume-based drug procurement towards normalization and standardization (Chang, 2021).

1.2. Background of the National Implementation of the Pharmaceutical Centralized Volume-Based Procurement Policy

China's pharmaceutical policy has undergone a long development, yet issues such as high drug prices leading to "expensive medical treatment" or "supporting medical services through drug sales" persist and urgently need resolution.

The initial drug procurement policy was neither open nor not transparent. The hospitals and medicine manufacturers formed a community of interest, keeping drug prices high and imposing the burden on patients. Additionally, since doctors' salaries were linked to prescriptions and treatment methods, patients often asked and received unnecessary treatments due to their limited medical knowledge and information asymmetry, resulting in excessive examinations and treatments Their worries led to high medical expenses. Cases of poverty induced by illness were widespread.

1.3. National Centralized Volume-Based Drug Procurement Policy

In response to these problems, in January 2019, the General Office of the State Council presented the *Notice on Issuing the Pilot Scheme for the National Centralized Drug Procurement and Use*. (General Office of the State Council, 2019). It was decided to initially implement a "competitive bidding first, bargaining price later" model in 11 pilot cities (the "4 + 7" pilot cities). The criteria for selecting the drugs were based on consistent evaluation. Conducted under the national guarantee, alliance for volume procurement were encouraged and operations were platform assisted.

On August 15, 2019, the Joint Procurement Office held the second symposium on centralized drug procurement in Shanghai, expanding the participations to enterprises and the scope to 25 provinces. The initial "4 + 7" pilot cities become a true "cross-regional alliance". On September 30, 2019, about six months after the government launch, the Joint Procurement Office published a notice on the successful results of the expended Centralized Drug Procurement. It signified the readiness for the official rollout of the scheme nationwide. On December 29, 2019, the Joint Procurement Office issued the *National Centralized Drug Procurement Document (GY-YD2019-2)* (Joint Procurement Office, 2019), initiating a second round of volume-based procurement involving 33 drug varieties. Launched on January 17, 2020, in Shanghai, the second round fostered the continued reduction in drug price and the expansion of procurement volumes (Tan & Chen, 2020).

1.4. Impact of Volume-Based Drug Procurement Policy on Pharmaceutical Companies.

In a nutshell, volume-based drug procurement is equivalent to a large-scale group purchase. The procurement volume is predetermined, and the lowest bidder wins the contract. Through competitive bidding among pharmaceutical companies, this policy aims to achieve lower prices through higher volumes, thereby reducing drug procurement costs (Du et al., 2020). The core principle is “volume pricing” and “price protection for volume” (Chen & Rao, 2019).

The implementation of this policy is not without opportunities and challenges for successful bidders. On the one hand, it enables the winning enterprises to quickly capture a higher market share and reducing distribution costs. On the other hand, through the above-mentioned bidding process, the sales price decreases. However, it doesn’t necessarily mean a profit decrease for the winning bidder, who become an important supplier of the centralized drug procurement system. As mentioned, the sales and distribution costs can be reduced, or the winning pharmaceutical manufacturing can adopt cost-control management strategies.

Non-winning companies face significant risks of losing market share, which can be devastating for smaller firms that lack advanced cost control and drug production capabilities and cannot sustain bids below cost (Li & Shen, 2020).

Thus, compared to traditional sales models, the pharmaceutical companies facing the centralized drug procurement project can engage in precise financial calculations. To determine the bidding price that would prevent profit decline, calculations should consider potential profit and market share losses in the case of unsuccessful bids. Mid-sized pharmaceutical companies are encouraged by the new “4+7” procurement policy to shift from inefficient, low-quality operations to efficient, high-quality ones, focusing resources and moving from imitation to innovation (Tan et al., 2020), ultimately winning the price and market share game.

(1) Under the “4+7” volume-based procurement policy, Chinese pharmaceutical manufacturing companies need enhance their research and development (R&D) and innovation capabilities to fully address the risks. posed by the policy. Specifically, by recruiting high-tech R&D talent and increasing R&D funding, companies can improve their drug development capabilities and apply for patents, aiming to become large-scale, branded pharmaceutical enterprises with unique and scarce resources, thereby increasing their chances of winning bids.

As the policy may force small and medium-sized enterprises (SMEs) into survival crises, larger companies can consider mergers and acquisitions for more integrated development. By leveraging combined resources in R&D, they can optimize human, material and financial resource allocation and maximize value, effectively balancing the profit constraints imposed by the "4+7" procurement policy.

(2) Facing the new policy, Chinese pharmaceutical manufacturers need to strategically manage and control costs by restructuring and changing operational methods. For example, by upgrading and optimizing internal production chains, companies can reduce costs while maintaining high quality and low prices, providing unique and irreplaceable advantages to flexibly respond to profit compression issues induced by the "4+7" policy. Additionally, by attracting innovative R&D talent, companies can enhance their overall innovation capabilities and effectively lower R&D and manufacturing costs through appropriate technological applications. It can achieve sustainable cost management. This cost management approach is a crucial means for Chinese pharmaceutical manufacturers to effectively cope with the new policy.

(3) The transformation and upgrading of the marketing model are also an important core competency for Chinese pharmaceutical manufacturers to effectively respond to the risks and challenges posed by the new “4 + 7” volume-based procurement policy. Specifically, companies should improve channel management to enhance their R&D resource advantages. This requires breaking away from traditional marketing concepts and advancing R&D innovation from market demand.

In other words, companies need to conduct thorough market research and clinical demand assessments to provide information for internal R&D, thereby developing products that meet the largest market demands and fill market gaps. Moreover, establishing internal and external innovative financing channels can attract and integrate diverse funding from the government, society, and individuals, providing strong financial support for R&D innovation and reducing related costs.

Finally, pharmaceutical manufacturers can establish collaborations with medical and pharmaceutical research institutions to achieve collaborative innovation, integrating production, learning, and research, reducing R&D costs, and enhancing external innovation network flexibility (Liu, 2020).

2. Literature Review

Through a series of regulatory policies, some long-standing issues in the pharmaceutical industry have been alleviated to a certain extent. The introduction of the volume-based procurement policy has brought significant changes to the current state of medical expenses through several mechanisms.

2.1. Substantial Reduction in Transaction Costs

Transaction costs are the expenses incurred to complete a transaction, including the costs of information dissemination, advertising, market-related transportation, negotiation, consultation, contracting, and supervision of contract execution. In the traditional decentralized procurement model, public medical institutions and physicians wield significant power. Manufactures, in their efforts to sell their products, must engage repeatedly with these institutions. Each negotiation, visit, and contract signing incurs transaction costs, sometimes even involving bribery. These costs are inevitably passed on to the drug prices, which increase the overall cost of medicine and impose a financial burden on patients. This cycle contributes to the problem of "expensive medical treatment," leading to poverty induced by illness, and severely disrupting the functioning of the pharmaceutical market in China (Fu, 2021).

Before the implementation of the volume-based procurement policy, pharmaceutical companies also had to allocate funds for marketing to increase their visibility. With the new policy in place, these companies no longer need to spend on advertising. Previously, pharmaceutical representatives had to negotiate with each hospital individually, but the policy has reduced the frequency and costs of such negotiations.

2.2. Joint Management of Supply and Demand by Government and Market

On the one hand, market management alone cannot prevent monopolistic behavior of large pharmaceutical companies, nor can it control the prices of essential drugs. It is

also ineffective in preventing public hospitals from inflating drug prices and in stopping counterfeit and substandard drugs from entering hospitals.

On the other hand, pure government management fails to allow supply and demand relationships to be flexibly reflected in policies. Government policy responses are always lagging behind the market. Inaction by the government can lead to hospitals exerting undue influence over drug procurement. Moreover, government officials typically have less understanding of the practical effects of drugs compared to medical institutions, and there are limitations to their knowledge.

Therefore, volume-based procurement policy mandates the joint participation of both government and market mechanisms to ensure a reasonable balance of supply, demand, and pricing.

3. Theoretical Mechanisms and Research Hypotheses

Based on the literature describing the background, process, and outcomes of the volume-based procurement policy, we will validate the following hypotheses using our model to determine their accuracy.

3.1. Research Hypotheses

Since volume-based procurement policy enables companies to quickly gain significant market share while simultaneously reducing the transaction costs, leading to an increase in market gross profit margins, we propose the first hypothesis:

Hypothesis 1: The policy has a positive impact sales gross profit margin of publicly listed pharmaceutical companies.

In the cities where the “4 + 7” policy is implemented, the execution vary across different cities. We categories the regions into southern and northern China, thus proposing the second hypothesis:

Hypothesis 2: In northern region, the volume-based procurement policy does not have a significant impact on operating revenue. In southern region, the policy has a significantly positive impact on operating revenue.

Within the "4+7" policy implementation cities, although all companies belong to the healthcare industry, the primary aim of the volume-based procurement policy is to reduce drug prices. We predict that its impact on medical device manufacturing companies will be minimal, leading to the following assumption:

Hypothesis 3: For pharmaceutical companies, the positive effect of the volume-based procurement policy on operating revenue is significant. For medical device companies, the positive effect of the policy on operating income is not significant.

The literature mentions that in the "4 + 7" volume-based drug procurement, some well-known pharmaceutical brands (e.g., Pfizer, Sanofi, etc.) were not selected because they offered the highest prices (Tan et al., 2020). Non-high-tech enterprises often have lower prices, and thus an advantage because in being selected. Therefore, we propose the following hypothesis:

Hypothesis 4: For high-tech pharmaceutical enterprises, the effect of the volume-based procurement policy on operating revenue not significant. For not-high-tech pharmaceutical enterprises, the effect on operating revenue is significant and positive.

3.2. Research Model

The Difference-in-Difference (DiD) approach is an effective approach to identify the treatment effects of a policy. The idea is to consider the implementation of a new policy as a "quasi-natural experiment" and to test for differences in the average change between the treatment group affected by the policy and the control group not affected by the policy (Liu & Wu, 2019). n this study, we analyze a sample of listed pharmaceutical companies in 433 prefecture-level and above cities in China. As of 2021, 11 cities in China have begun pilot trials of the volume-based procurement policy, providing a solid foundation for using the DiD method to test the impact of this policy on corporate operating revenue.

Specifically, the listed pharmaceutical companies involved in the 11 pilot cities with volume procurement constitute the treatment group, while the companies in cities that have not implemented the policy formed the control group. The volume-based procurement pilot policy was introduced in 2018 and implemented in 2019, with a three-year implementation period. Therefore, we choose 2019 as the policy implementation time node: the period before 2019 serves as the control group, and 2019 and thereafter as the experimental group. Given the consistent implementation period, we adopt the Difference-in-Differences model, constructing the following two-way fixed effects econometric model (Heyman et al., 2007) to measure the net effect of the volume-based procurement policy on the operating revenue of listed pharmaceutical companies in China.

$$Lnincit=\beta 0+\beta 1Didit+\beta 2Zit+\mu it+vit+\varepsilon it$$

where i=1, 2, …, 443; t=2016, 2017, …, 2021. The coefficient $\beta 1$ of $Didit$ in equation (1). referencing the Difference-in-Differences method by Beck et al. (2010), is the focal coefficient of the DiD model, reflecting the net effect of the procurement policy on operating revenue. The positive or negative sign and the magnitude of $\beta 1$ indicate the extent of the impact, with a positive and larger value signifying a greater positive effect, and vice versa. $Lnincit$ is the dependent variable, representing the operating revenue of each firm. Zit is a set of control variables that account for other factors influencing operating revenue. i indicates the firm and t indicates the year. μit is the time fixed effects. vit is the firm fixed effect. εit is the error term.

4. Empirical Methods and Data Description

4.1. Data Source

The volume-based drug procurement policy data (such as policy pilot information, business performances, and regional characteristics) are obtained from official reports. Firm characteristics (such as firm type, firm nature, high-tech status, and gross profit margin) are obtained from the WIND database from 2015–2021. Patent development data is obtained from the CNRDS database from 2015–2021. Considering data availability, finally, this paper selects the panel data of a sample of 433 city-listed pharmaceutical companies from 2015–2021, with a total of 2259 observations.

4.2. Variable Measurement

The dependent variable in this study is the corporate performance which is measured by taking the logarithm of operating revenue. The independent variable is the procurement policy, which is introduced in 2018 and implemented in 2019 with an implementation period of 3 years. Hence, 2019 is chosen as the policy implementation time point. The 11 cities that started implementing the policy (Beijing, Tianjin, Shanghai, Chongqing, Shenyang, Dalian, Xiamen, Guangzhou, Shenzhen, Chengdu, and Xi'an) constitute the experimental group, while the remaining cities form the control group. The policy implementation dummy variable is set by interacting the policy implementation time dummy variable with the company dummy variable.

In terms of control variables, this paper selects regional and corporate characteristics to control the main effects. Regional characteristics include the northern and southern provinces, where the northern region is coded as 0 and the southern region as 1. The enterprise characteristics include the enterprise industry type, i.e., whether it is a pharmaceutical enterprise or a medical device enterprise, 1 for pharmaceutical enterprises and 0 for medical device enterprises. Whether it is a state-owned enterprise, 1 for state-owned enterprise (SOE) and 0 for not. Whether it is a high-tech enterprise, 1 if it is and 0 if it is not. It also includes the enterprise’s gross profit margin, and the

enterprise's R&D investment. For the R&D investment, logarithm is taken.

Table 1 Variable Measurement and Data Source

Variable Name	Variable Measurement	Date Source
Operating income	Enterprise operating income is taken as the logarithm	WIND Database
Purchasing Policy	1 for the experimental group and 0 for the control group	WIND Database
North-South Region	0 for the northern region and 1 for the southern region	WIND Database
Government-owned enterprises	1 for government-owned enterprises and 0 for non-government-owned enterprises	WIND Database
High and New Technology	High-tech enterprise is 1, non-high-tech enterprise is 0	WIND Database
Gross sales margin	Gross sales margin	WIND Database
Research and development investment	Patent R&D investment is taken as the logarithm	CNRDS Database
Business Industry	1 for pharmaceutical companies and 0 for medical device companies	WIND Database

4.3. Empirical Analysis

The empirical analysis includes descriptive statistical analysis, multiple covariance analysis, Housman tests, difference-in-differences regression analysis, robustness analysis and heterogeneity test.

4.4. Descriptive Statistical Analysis

Descriptive statistical analysis of the variables was performed and the results are shown in Table 2. The mean value of the dependent variable operating revenue is 21.24, with a median of 21.14, and a standard deviation of 1.34, indicating a large gap between samples, with a minimum value of 0 and the maximum value of 26.10. The mean value of the independent variable volume-based procurement pharmaceutical policy is 0.18, the median is 0. The standard deviation is 0.39, with a minimum value of 0 and the maximum value of 1, indicating that the number of listed pharmaceutical companies in the pilot is still relatively small.

In terms of control variables, the mean value of SOEs is 0.22, with a median 0, a standard deviation 0.42, a minimum value of 0 and a maximum value of 1. The mean

value of North-South region is 1.66, with a median of 2, a standard deviation 0.47, a minimum value of 0 and a maximum value of 1. The mean value of high-tech is 0.72, with a median of 1, a standard deviation of 0.45, a minimum value of 0 and a maximum value of 1. The mean value of gross profit margin is 0.51, the median is 0.51, the standard deviation is 0.24, the minimum is -2.63, and the maximum is 1. The mean value of R&D investment is 17.36, the median is 17.97, the standard deviation is 3.66, the minimum is 0, and the maximum is 22.98. The mean value of business industry is 1.77, the median is 2, the standard deviation is 0.42, the minimum is 0, and the maximum value of 1.

Table 2 Descriptive Statistical Analysis

Variables	Sample	Mean Value	Median Values	Standard Deviation	Minimum Value	Maximum Value
Operating Revenue	2259.00	21.24	21.14	1.34	0.00	26.10
Policy	2259.00	0.18	0.00	0.39	0.00	1.00
North-South Region	2259.00	1.66	2.00	0.47	0.00	1.00
State-Owned Enterprises	2259.00	0.22	0.00	0.42	0.00	1.00
High-Tech Status	2259.00	0.72	1.00	0.45	0.00	1.00
Gross Profit Margin	2259.00	0.51	0.51	0.24	-2.63	1.00
R&D Investment	2259.00	17.36	17.97	3.66	0.00	22.98
Enterprise Industry Type	2259.00	1.77	2.00	0.42	0.00	1.00

4.5. Multicollinearity Analysis

Multicollinearity among variables is an important prerequisite for determining whether a baseline regression can be performed and is an important measure of whether the selection of variables is reliable. As shown in Table 3, the multicollinearity analysis of the variables reveals that all variable VIF values are far below 5, and the average VIF value is also below 5. This preliminary judgment indicates that there is no serious multicollinearity among the variables, allowing for subsequent regression analysis.

Table 3 Multicollinearity

Variables	VIF	1/VIF
Gross Profit Margin	1.37	0.728008
R&D Investment	1.28	0.778723
Enterprise Industry Type	1.21	0.825743
R&D Investment	1.15	0.871652
High-Tech Status	1.08	0.928377
State-Owned Enterprises	1.05	0.953148
Policy	1.04	0.959279
Mean VIF	1.17	

4.6. Correlation Analysis

This study performs correlation analysis on the data to preliminarily determine the basic relationships between variables and to conduct subsequent analysis based on existing conditions. The correlation analysis preliminarily shows that the procurement policy has a significant positive impact on operating revenue, with an impact coefficient of 0.048, initially confirming the basic hypothesis of this study.

In terms of control variables, state-owned enterprises and R&D investment have a significant positive impact on operating revenue, with impact coefficients of 0.230 and 0.187, respectively. Other control variables, such as high-tech status, gross profit margin, and industry type, have significant negative impacts on operating revenue, with impact coefficients of -0.167, -0.214, and -0.121, respectively. It can be preliminarily predicted

that the industry type may have a heterogeneous impact on the coefficient of policy impact on operating revenue. According to the above correlation analysis, we can preliminarily determine: (1) the hypotheses proposed in this paper are basically reasonable, but still need further analysis with a rigorous regression model: (2) the impact coefficients between multiple variables are all below 0.6, indicating that there is no severe multicollinearity among the variables, allowing for regression analysis.

Table 4 Correlation Analysis

Variables	Operating Revenue	Policy	North-South Region	State-Owned Enterprises	High-Tech Status	Gross Profit Margin	R&D Investment	Enterprise Industry Type
Operating Revenue	1							
Policy	0.048**	1						
North-South Region	-0.0100	-0.0300	1					
State-Owned Enterprises	0.230***	0.054***	-0.121***	1				
High-Tech Status	-0.167***	0.0340	0.00700	-0.127***	1			
Gross Profit Margin	-0.214***	0.122***	-0.072***	-0.191***	0.274***	1		
R&D Investment	0.187***	0.113***	0.043**	-0.037*	0.300***	0.378***	1	
Enterprise Industry Type	-0.121***	-0.074***	-0.107***	-0.0200	0.156***	0.347***	0.279***	1

Note: ***, **, * denote significant at 1%, 5%, and 10% confidence levels, respectively, with robust standard errors in parentheses.

4.7. Hausmann Test

The Hausman test is performed on the relevant variables, as shown in Table 5. It selects panel data of a sample of 433 city-listed pharmaceutical companies from 2015 to 2021. We consider the changes in both cross-sectional and longitudinal time series data. Therefore, we construct two models: Model 1 selects either a fixed effects or random effects model through the Hausman test, and Model 2 considers time effects, thus setting the time dummy variable for the *i*-th year of the policy change. The Hausman test results show a P-value of 0.0000, rejecting the null hypothesis of "the random effects model is the best." Simultaneously, using 2019 as a reference for testing the other years' dummy variables, the P-value is 0.0000, rejecting the null hypothesis of "the time fixed effect is 0." Therefore, we choose to establish a two-way fixed effects model to control for individual and time fixed effects, avoiding estimation bias caused by omitted variables.

Table 5 Hausmann Test

chi2(13) = (b-B)'[(V_b-V_B)^(-1)] (bB)
= 210.81
Prob> chi2= 0.0000

4.8. Difference-in-Difference Regression

As shown in Table 6, this paper gradually includes control variables to verify the robustness of the regression results. Model 1 does not include control variables, while Models 2 to 5 gradually include control variables until Model 5 includes all control variables. Model 1 shows that the volume-based drug procurement policy has significantly increased the operating revenue of listed pharmaceutical enterprises in China. Its increase is 17.7%, and the impact is significant within 0.05; Models 2 to 5 show that even after including control variables, the procurement policy still significantly increases the operating revenue of listed pharmaceutical companies by 17.5%, with significance within 0.05. Hypothesis 1 is verified. This result demonstrates that the procurement policy can bring substantial market shares to companies in a short period, and simultaneously reduce channel costs.

In the control variables, only the North-South region, gross profit margin and R&D investment have a substantial impact on the operating revenue of listed Chinese pharmaceutical companies implementing the procurement policy. But state-owned enterprise status and high-tech status do not have significant impacts. Regional characteristics have a significant negative impact on operating revenue, with an impact coefficient of -0.719. However, gross profit margin and R&D investment have a significant positive impact. The impact coefficient is 0.747 for gross profit margins and 0.0187 for R&D investment. For both, the impact is significant within 0.01. Regional characteristics have a notable influence on the impact of the procurement policy on the operating revenue of listed pharmaceutical companies, warranting further heterogeneity analysis.

Table 6 Regression Analysis

Variables	(1) lninc	(2) lninc	(3) lninc	(4) lninc	(5) lninc
DiD	0.177**	0.180**	0.180**	0.180**	0.175**
	(0.0746)	(0.0748)	(0.0745)	(0.0747)	(0.0743)
Region		-0.485***	-0.476***	-0.483***	-0.534***
		(0.0554)	(0.0617)	(0.107)	(0.124)
State-Owned Enterprises			0.0266	0.0273	0.0256
			(0.128)	(0.127)	(0.129)
High-Tech Status				0.00999	-0.0204
				(0.122)	(0.120)
R&D Investment					0.0265***
					(0.00870)
Time Effect	Control	Control	Control	Control	Control
Fixed Effects	Control	Control	Control	Control	Control
Constant	20.82***	21.63***	21.61***	21.61***	21.28***
	(0.0363)	(0.120)	(0.130)	(0.141)	(0.211)
Observations	2,259	2,259	2,259	2,259	2,259
R-Squared	0.107	0.108	0.108	0.108	0.115
Number of id	443	443	443	443	443

Note: ***, **, * denote significant at 1%, 5%, and 10% confidence levels, respectively, with robust standard errors in parentheses.

As shown in Table 7, the study employs a stepwise approach to include control variables for regression analysis to verify the robustness of the results. Model 1 does not include control variables, while Models 2 to 5 gradually include control variables until Model 5 includes all control variables. Model 1 indicates that the procurement policy significantly increases the gross profit margin of listed pharmaceutical companies by 2.67%, with significance within 0.1. Models 2 to 5 show that even after including control variables, the procurement policy still significantly increases the operating revenue of listed pharmaceutical companies by 2.31%, with significance within 0.1. Hypothesis 1 is verified.

Among the control variables, only regional characteristics and R&D investment have substantial impacts on the operating revenue of listed pharmaceutical companies implementing the procurement policy, while state-owned enterprise status and high-tech status do not have significant impacts. Regional characteristics have a significant positive impact on gross profit margin, with an impact coefficient of 0.249, while R&D investment also has a significant positive impact, with an impact coefficient of 0.0105.

Table 7 Regression Analysis

VARIABLES	(1) Gross Profit Margin	(2) Gross Profit Margin	(3) Gross Profit Margin	(4) Gross Profit Margin	(5) Gross Profit Margin
DiD	0.0266*	0.0248*	0.0247*	0.0251*	0.0231*
	(0.0142)	(0.0142)	(0.0141)	(0.0140)	(0.0135)
Region		0.248***	0.251***	0.269***	0.249***
		(0.0770)	(0.0747)	(0.0830)	(0.0657)
State-Owned Enterprises			0.0101	0.00838	0.00771
			(0.0321)	(0.0323)	(0.0329)
High-Tech Status				-0.0267	-0.0387
				(0.0304)	(0.0279)
R&D Investment					0.0105**
					(0.00475)
Time Effect	Control	Control	Control	Control	Control
Fixed Effects	Control	Control	Control	Control	Control
Constant	0.478***	0.0648	0.0574	0.0491	-0.0820
	(0.00757)	(0.128)	(0.125)	(0.135)	(0.119)
Observations	2,259	2,259	2,259	2,259	2,259
R-Squared	0.023	0.032	0.032	0.033	0.071
Number of id	443	443	443	443	443

4.9. Robustness Analysis: Parallel Trend Test and Placebo Test

Although the previous analysis has preliminarily confirmed that the volume-based procurement policy has significantly improved the operating revenue and gross profit margin of Chinese listed companies, this result may still be affected by missing variables and self-selection issues. To verify the reliability of the DiD method and the robustness of the benchmark regression results, this study conducts tests from the following aspects.

(1) Parallel Trend Test

The DiD model should satisfy the “parallel trend assumption”, which means that without policy intervention, the time effects or trends of the treatment group and the control group should be basically the same. In other words, if there are no external shocks from the policy, the development trends of the firms in the treatment and control groups should be parallel, exhibiting similar time trends, or at least no systematic differences over time. To verify whether there are any differential changes in operating revenue between the treatment and control group samples before the policy implementation, we use event analysis to conduct the parallel trend test. Consequently, the following econometric model is constructed:

$$Lninc_{it} = \beta_{-3}DID_{-3} + \cdots + \beta_0 DID_0 + \cdots + \beta_3 DID_3 + \beta X + \lambda_i + \gamma_i + \varepsilon_{it} \quad (2)$$

In equation (2), DID_0 indicates the dummy variable where the policy starts to be implemented, DID_{-m} indicates the dummy variable for the m-th year before the policy implementation (m=1, 2, 3, 4). DID_n indicates the dummy variable for the n-th year after the policy implementation (n=1, 2, 3). It is important to note that since the policy implementation did not occur simultaneously in all cities, DID_0 denotes different years for different cities.

The results of the parallel trend test in Figure 1 report the magnitude of the estimated parameters with operating income as the explanatory variable and the corresponding 95% confidence intervals. It can be found that none of the estimated coefficients of the dummy variables for the years before the implementation of the policy pass the 5% significance level, and satisfying the parallel trend assumption. After the implementation of the policy, the significant increase in operating revenue, relative to those without the policy, is not a result of pre-existing differences.

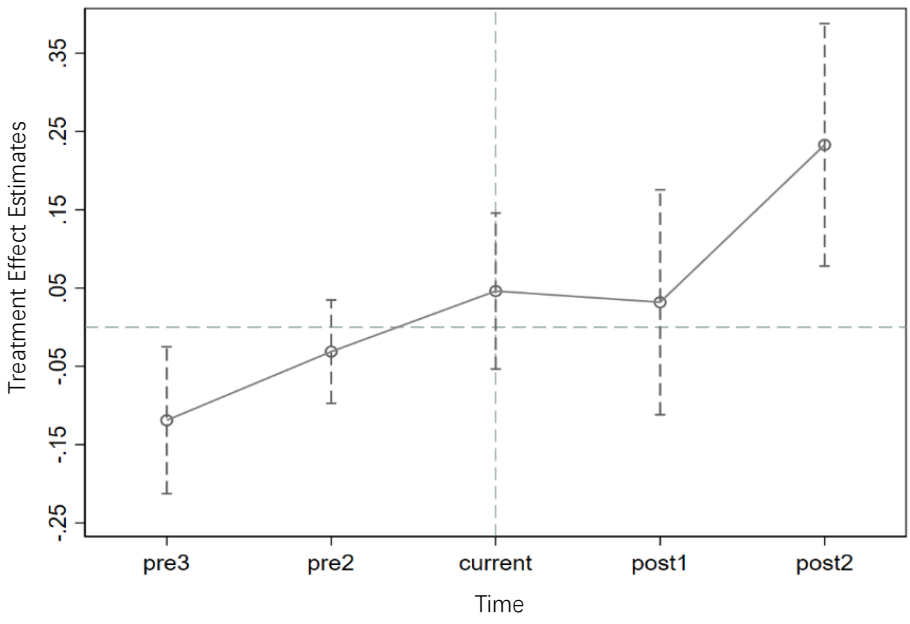

Figure 1 Parallel Trend Test of Operating Income

Figure 2 reports the results of the parallel trend test using gross profit margin as the dependent variable. Similar to the previous figure, the estimated coefficients for the pre-policy dummy variables are not significant at the 5% level, satisfying the parallel trend

assumption. This suggests that the significant increase in gross profit margin for firms after policy implementation is not due to pre-existing differences.

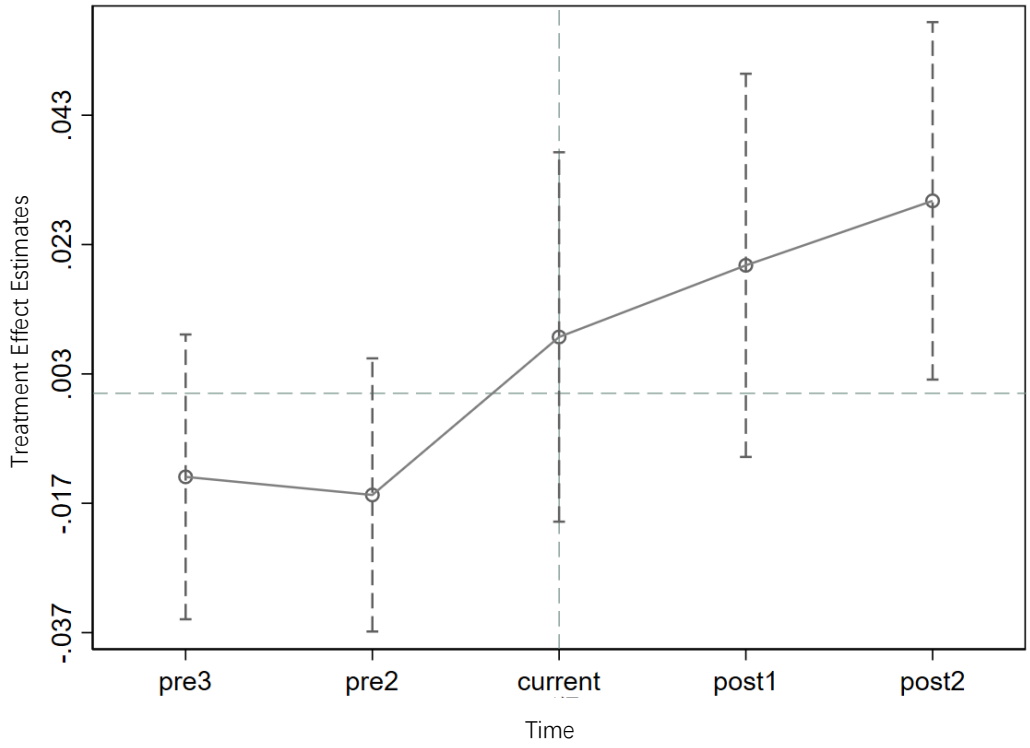

Figure 2 Parallel Trend Test of Sales Gross Profit Rate

(2) Placebo Test

Given the parallel trend test has passed, we follow the method of Liu et al. (2020) and conduct a placebo test by creating a fictitious treatment group to determine if the effect of the volume-based procurement policy is due to other random factors. In this paper, the placebo test is conducted by randomly setting up treatment groups. The listed pharmaceutical companies in Chinese cities are grouped, with a random sample drawn from the policy implementation group, reconstructing the policy implementation interaction term Post*Teat for the placebo test. Specifically, 443 samples are randomly selected from 2259 samples as the treatment group, with the remaining firms as the control group, and the DiD estimation is performed again using the randomly grouped samples. Unless the random sample of firms and the control sample of the original policy are identical, the estimation results should not be significant. If the estimation results are still significant after random grouping, it indicates that the baseline the results of the quasi-regression are biased.

In order to prevent the impact of random small probability events on the placebo test, 500 repeated cycle experiments were conducted. Figure 3 and Figure 4 show the probability density distribution of the estimated value and its related estimates. The results indicate that the coefficients obtained from the repeated cycle experiments are distributed around zero and conform to a normal distribution.

This demonstrates that the benchmark regression results are not influenced by random factors or omitted variables, validating the effectiveness of the policy in improving operating revenue and gross profit margin. This further shows that the volume-based drug procurement policy has significantly increased the operating revenue and gross profit margin of listed pharmaceutical enterprises in China.

The volume-based drug procurement policy significantly enhances the operating revenue and gross profit margin of listed pharmaceutical companies in China, indicating that the policy has a significant positive impact on the operating revenue and gross profit margin of these companies, and the research results are not influenced by random factors or omitted variables, thus possessing a certain degree of reliability and scientific accuracy.

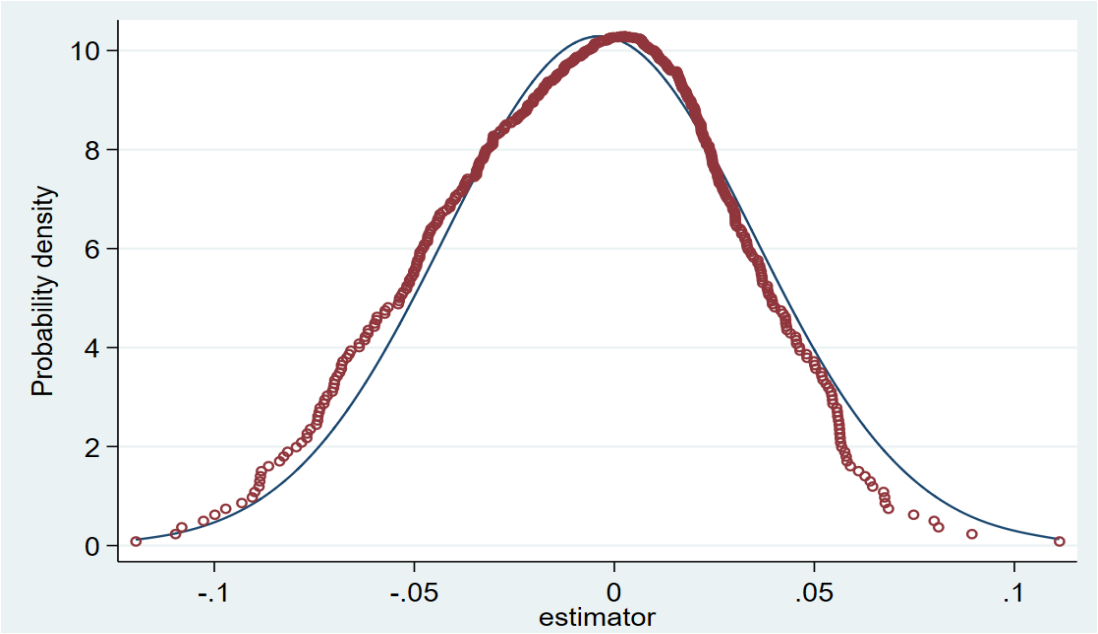

Figure 3 Placebo Test

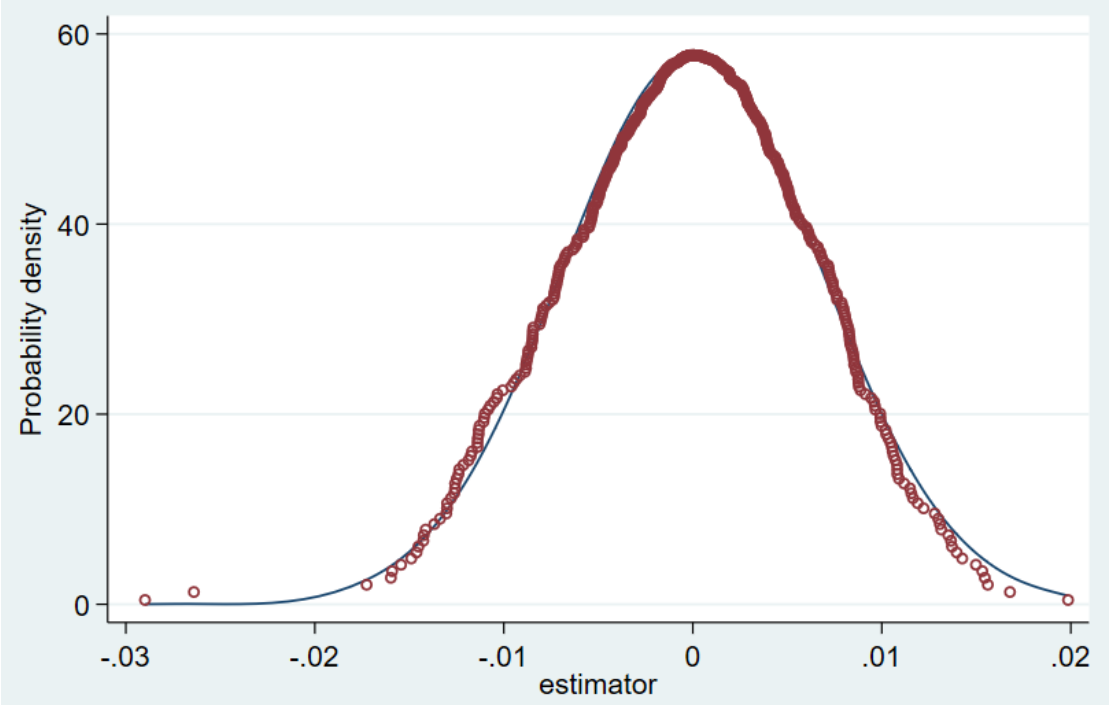

Figure 4 Placebo Test

4.10. Heterogeneity Test

The impact of the volume-based drug procurement policy on the operating revenue of listed pharmaceutical companies varies across different regions. At the regional level, the policy's impact on operating revenue is not significant in northern regions but is significantly positive in southern regions. The impact coefficient is 0.140, which is lower than that of the total sample, and hypothesis 2 is verified. It may indicate that the industrial environment and policy implementation in southern regions may be more in line with the objectives of the volume-based procurement policy, whereas the northern regions do not show a significant impact. This suggests that the operating revenue of listed pharmaceutical companies in the northern regions is not affected by the policy, further demonstrating that the implementation methods of the same policy can differ across cities within the "4+7" pilot cities.

At the enterprise type level, the positive effect of volume-based procurement policy on operating revenue is significant for pharmaceutical firms, with an impact coefficient of 0.124, whereas it is not significant for medical device companies. Hypothesis 3 is verified. This indicates that the impact of the volume-based procurement policy on operating revenue does differ across firm types. The policy has a significant positive

impact on the operating revenue of pharmaceutical companies but not on medical device companies. This suggests that the main purpose of the volume-based procurement policy is to reduce the drug prices, having a smaller impact on medical device manufacturers.

The effect of volume-based procurement policy is not significant for pharmaceutical companies that are high-tech, whereas for not high-tech pharmaceutical companies, the policy has a significant positive effect on their operating revenue, with an impact coefficient of 0.358. Hypothesis 4 is verified. The volume-based procurement does not significantly impact high-tech pharmaceutical companies but does significantly impact non-high-tech pharmaceutical companies. This indicates that digitally transformed companies are not affected by the volume-based procurement policy. Companies without digital transformation relying on the scale effect to achieve corporate revenue growth are more impacted. The policy shows a clear preference, significantly differing in its impact on high-tech and non-high-tech enterprises. This may be because, within the "4+7" pilot cities, some well-known pharmaceutical companies (such as Pfizer, Sanofi, etc.) were not selected in the “4 + 7” implementation cities due to their high bids. On the contrary, non-high-tech enterprises have the advantage of being selected because of their lower medicine prices.

Table 8 Heterogeneity Analysis

	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
	Northern Region	Southern Region	Medical Devices	Pharmaceutical Companies	High-Tech	Not High-Tech
Variables	Operating Revenue	Operating Revenue	Operating Revenue	Operating Revenue	Operating Revenue	Operating Revenue
Policy	0.202	0.140*	0.285	0.124*	0.0451	0.358**
	-0.151	-0.0747	-0.25	-0.0701	-0.0694	-0.175
State-Owned Enterprises	0.0922	0.00761	0.674**	-0.0685	-0.14	0.329*
	-0.127	-0.173	-0.336	-0.11	-0.124	-0.17
High-Tech Status	0.0301	0.0102	0.194	-0.0388		
	-0.165	-0.128	-0.222	-0.116		
Gross Profit Margin	1,364**	0.36	0.895*	0.617	0.43	0.650*
	-0.668	-0.258	-0.491	-0.375	-0.409	-0.346
R&D Investment	0.0106	0.0278***	0.00288	0.0407***	0.103	0.00926
	-0.0095	-0.00924	-0.00871	-0.0138	-0.0643	-0.00651
North-South Region			-0.229	-0.880***		-0.706***
			-0.359	-0.177		-0.202
Time Effect	Control	Control	Control	Control	Control	Control
Fixed Effects	Control	Control	Control	Control	Control	Control
Constant	20.06***	20.10***	20.87***	21.20***	18.62***	22.03***
	-0.382	-0.191	-0.575	-0.209	-1,097	-0.317
Observations	762	1,497	522	1,737	1,626	633
R-Squared	0.059	0.318	0.061	0.274	0.414	0.042
Number of id	145	300	110	333	360	123

Note: ***, **, * denote significant at 1%, 5%, and 10% confidence levels, respectively, with robust standard errors in parentheses.

5. Analysis of Empirical Results

The Chinese government has undertaken extensive reforms in the health care system from production, distribution, sales and usage. These reforms continuously explored and selected new medicine procurement models to control the cost of drug purchases.

This paper uses a 7-year sample of 2259 from 2015 to 2021, combined with a Difference-in-Difference model. to investigate the impact of volume-based procurement policy on the operational performance of pharmaceutical companies by regulating prices and procurement volumes. Robustness test and heterogeneity analysis were also conducted, yielding the following results:

For the overall sample, the volume-based procurement policy has a positive impact on the operating revenue of listed pharmaceutical companies. In the northern region, the effect of volume-based procurement policy on operating revenue is not significant, while in the southern region, the positive effect of volume-based procurement policy on operating revenue is significant. For pharmaceutical companies, the positive effect of volume-based procurement policy on operating revenue is significant. For medical device companies, the effect of volume-based procurement policy on operating revenue is not significant. For high-tech pharmaceutical enterprises, the impact of the volume-based procurement policy on operating income is not significant. However, for pharmaceutical enterprises that are not high-tech, the positive impact of the procurement policy on operating income is significant.

In summary, volume-based procurement policy has significantly impacted China's healthcare system reform, achieving costs reduction. In the future, China's drug procurement will be more centralized, fostering healthier development in the pharmaceutical market.

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