Evaluating the Impact of National Volume-Based Procurement: Evidence from China

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13 December 2024

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By Zeyang Wang*

The Volume-Based Procurement (VBP) undertaken by governments significantly influence the healthcare landscape across numerous nations. Initiated in 2018 and broadened in 2019, the National Volume-Based Procurement in China has experienced eight phases of execution throughout key regions. This research utilizes a Difference-in-Differences (DID) framework to assess the effects of centralized procurement on pharmaceutical results. The results indicate that: (1) in the 2018 pilot phase, there was a significant reduction in drug expenditures, an increase in quantities, and a marked decline in prices; and (2) when analyzing the impact of all seven subsequent rounds, both expenditures and prices continued to show significant decreases, although quantities also saw a considerable decline.

The Organization for Economic Co-operation and Development (OECD) defines public procurement as the purchase by governments and state-owned enterprises of goods, services and works. In 2019, public procurement expenditures constituted an average of 12% of GDP, comprised about one-third of governmental outlays, and exceeded 6 trillion EUR yearly among OECD member nations. The relevance of public procurement emphasizes the need of evaluations to guarantee their best utilization and efficiency.

In China, government procurement is an essential instrument for enhancing citizens' quality of life and achieving governmental objectives. Healthcare, as the fundamental industry of society, requires comprehensive regulation and engagement. Following the healthcare system reform in 2017, the government has persistently enacted policies to enhance the medical system and elevate patients' healthcare experiences. To diminish reliance on pharmaceutical sales for hospital funding and minimize patients' medication costs, the government has actively pushed improvements in drug procurement models, implementing the Volume-Based Procurement (VBP) plan. This technique reduces drug prices, enabling patients to afford long-term treatment and permitting physicians to prescribe more effective, previously costly medications. The bulk of pharmaceuticals under centralized procurement are utilized for the treatment of chronic and severe ailments, including hypertension, mental disorders, viral hepatitis, and malignant tumors, resulting in substantial long-term medication costs for patients. Additionally, in the decentralized procurement model, pharmaceutical businesses frequently over-

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looked innovation, quality, and cost management, primarily depending on sales channels and subjecting workers to legal liabilities. The establishment of centralized procurement, which prioritizes evaluations of quality and efficacy consistency for generic pharmaceuticals, has redirected the attention on drug quality and efficacy from the industry to the general public due to increased competition among makers of identical generic drugs.

Based on official government data, the eight rounds of centralized procurement done to date have resulted in an average reduction of nearly 50% in the unit price of each selected medication in China. Simultaneously, the costs of unselected medications sharing the same generic name have exhibited oscillations, with reductions ranging from 10% to 40% (Biao et al., 2023).

However, the procurement policy also poses certain potential challenges. Healthcare services, being an irregular and unpredictable commodity, possess distinct economic attributes.(Arrow, 1965) Consequently, fluctuations in pharmaceutical costs cannot be entirely elucidated by basic market models and include a certain level of unpredictability. Studies indicate that following the implementation of healthcare reform policies, hospitals, unable to benefit from centralized drug procurement, may choose to replace these drugs with non-procurement alternatives or offset the loss by raising fees for diagnostic tests and treatments. (Chen, Song and Zhang, 2018; Wu, 2019) Many studies also indicate that governments have incentives to manipulate official statistics to influence public opinion (Arrow, 1965; Feldstein, 2017; Lorentzen, 2014), hence creating the possibility of an overestimation of price reductions.

This study assesses the impact of centralized procurement utilizing drug purchasing data from selected hospitals between 2016 and 2022. Current studies in this domain frequently exhibit insufficient empirical evidence and are predominantly confined to evaluating the results of a singular procurement cycle within a certain city or region. This analysis utilizes an extensive dataset encompassing numerous procurement rounds within a broader context, so addressing existing constraints and bridging a substantial gap in the literature, which enhances the understanding of the policy's impact.

The results indicate the effectiveness of the procurement policy. The intervention results in a reduction in expenditures, an increase in quantity, and ultimately a decrease in price. However, the varying responses of outcomes across different categories of medications highlight the need for the government to adopt a targeted approach. Policies should address the unique challenges of each category to enhance procurement effectiveness.

The structure of the paper is as follows: Section I presents background information and potential issues regarding the National Volume-Based strategy in China. Section II outlines the data employed for the empirical investigation. Section III establishes the methodology and empirical findings for the 2018 centralized procurement and the seven rounds of procurement respectively, accompanied by robustness checks. Section IV has concluded.

I. Background

A. Overview of National Volume-Based Procurement Policy in China

China's healthcare system faces numerous long-standing challenges, including the unreasonable escalation of medical expenses (Yao, 2014), the lack of clarity regarding the rights and responsibilities of various stakeholders in social security (Gongcheng, 2003), the inequitable distribution of medical resources (E, 2009), and the inflated prices of pharmaceuticals resulting from medical institutions exploiting their monopolistic positions (Hengpeng, 2007), among other issues. In 2017, the State Council's "13th Five-Year Plan for Deepening the Reform of the Medical and Health System" articulated its foundational principles, emphasizing the necessity of a coordinated reform encompassing medical services, medical insurance, and pharmaceuticals.On May 31, 2018, the National Healthcare Security Administration was officially established. This institution is tasked with the management of medical insurance for both urban and rural employees and residents. Its responsibilities include the supervision and regulation of drug and medical service pricing, the execution of medical assistance duties, the mitigation of excessive medical practices, and the reduction of medical insurance fund expenditures. Additionally, it aims to lower communication costs, enhance work efficiency, and ensure that all individuals benefit from uniform protection under the same system, thereby promoting social equity.

The centralization of drug procurement constitutes a significant strategy in the reform of the medical and health system. In particular, the National Healthcare Security Administration, along with other relevant departments, coordinates with various provinces to establish procurement alliances, thereby explicitly delineating the quantity of drug procurement requirements for centralized purchasing. This approach seeks to attain substantial reductions in pharmaceutical prices via bulk purchasing, consequently mitigating the financial burden of drug expenses on patients; decreasing transaction costs for enterprises, enhancing the circulation environment, and refining the industry ecosystem; standardizing the processes of drug circulation to ensure the safety of medications; directing medical institutions to regulate drug utilization and facilitating the reform of public hospitals; and investigating enhancements to the centralized drug procurement mechanism and the market-driven pricing of pharmaceuticals. Figure 1 illustrates the particular procedure involved in the centralized procurement of pharmaceuticals by the government.

On January 1, 2019, 31 pilot drug kinds were chosen among generic pharmaceuticals that have successfully undergone consistency evaluations of quality and efficacy in 11 cities: Beijing, Tianjin, Shanghai, Chongqing, Shenyang, Dalian, Xiamen, Guangzhou, Shenzhen, Chengdu, and Xi'an. This signified the commencement of the first batch of centralized drug procurement. Following the positive results from the pilot program, the national consolidated procurement and usage initiative was formally extended across the country on September 25,

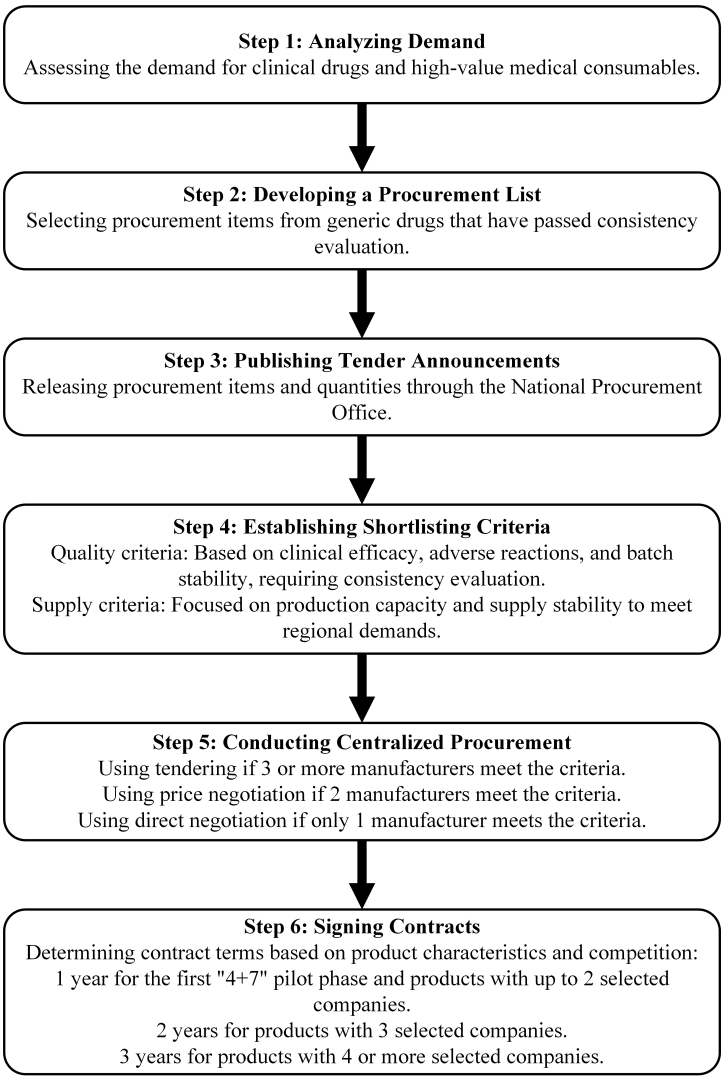

FIGURE 1. PROCESS OF CENTRALIZED PROCUREMENT

Note: Assessment of consistency is an examination of the efficacy consistency between generic medications and their original counterparts. Generic drugs are defined as pharmaceuticals that possess identical active ingredients, dosage forms, routes of administration, and therapeutic effects as the reference drugs they replicate. Original drugs are defined as the initial pharmaceuticals that receive approval for marketing, either domestically or internationally, based on comprehensive and adequate safety and efficacy data that underpins the marketing authorization.

2019. Subsequently, centralized drug procurement entered a phase of normality and institutionalization. As of now, nine batches of centralized medication procurement have been executed, with the particular dates and quantities of procured types for each round outlined in Table 1.

Table 1—Centralized Procurement Dates and Variety Quantities

Round	Date	Variety
1	2018.12	31
First expansion batch	2019.9	25
2	2020.1	32
3	2020.8	55
4	2021.2	45
5	2021.6	61
6	2021.11	16
7	2022.7	60
8	2023.3	39

B. Potential problems of National Volume-Based Procurement Policy

Government procurement is widely implemented across many countries worldwide. The economic mechanism underpinning this approach is explained by the Quantity Discount model (Richard B. and J. Aquilano, 1981; Martin K. and W. Miller, 1962; Peterson and Silver, 1979; G. and Whitin, 1963) within the framework of inventory control, which includes lot sizing with the possibility of quantity discounts. The effectiveness of this procurement model is further supported by modern industry practices (Sethi, 1984; Monahan, 1984; Ke and Bookbinder, 2012; Hohner et al., 2003; Li and Wang, 2007; Yang et al., 2017).

Despite its potential benefits, many studies have highlighted several challenges associated with centralized procurement, suggesting that its efficiency can be affected by various factors. For instance, some public sectors have incurred exorbitant procurement costs for public goods due to inefficient governance models (Bandiera, Prat and Valletti, 2009). Corruption is another prevalent issue, particularly in the allocation of public procurement contracts. Vote trading and tunneled cash often benefit politicians in exchange for procurement contracts, undermining both the long-term management and productivity of corporations as well as the government's operational capacity (Mironov and Zhuravskaya, 2016; Cohen and Malloy, 2014). Furthermore, longer tenures in office tend to foster collusion between government officials and local bidders (Coviello and Gagliarducci, 2017). Poorly designed contracts and auction processes, such as excessively long contract durations, can increase the risk of being locked into inefficient suppliers and raise the costs of switching suppliers (MacKay, 2022). In addition, inappropriate incentives and the protective effect of local products may stifle industry innovation, preventing high-innovation products from contributing to broader economic returns (Slavtchev and Wiederhold, 2016; Wei and Yuting, 2020).

Unlike industrialized markets, China's market lacks a comprehensive and effective marketing mechanism, leading to challenges such as delayed oversight, insuf-

ficient market competition, and excessive political interference (Zhao et al., 2021). The overuse of political interventions has, in some cases, allowed certain firms to achieve monopolistic positions (Kang and Hao, 2021). Furthermore, some corporations have reported increased shortages of specific drugs due to inadequate raw materials or limited production capacity, exacerbated by the unusually large scale of centralized procurement. This, in turn, may negatively impact the interests of these firms and disrupt the pharmaceutical supply chain (Zhou et al., 2023). Investigations have also shown that large-scale procurement can lead to wastefulness, as the utilization of certain treatments far exceeds their practical need (Zaixiang and Qingqing, 2020). Additionally, rises in the procurement prices, volumes, and expenditures of alternative drugs—those not covered by the policy but clinically substitutable for the bid-winning drugs—indicate that healthcare institutions may prioritize financial incentives over cost-saving objectives, potentially undermining the broader benefits of the procurement policy (Zhao and Wu, 2023).

Many previous studies have discussed the advantages and shortcomings of the strategy, but without robust empirical evidence, which weakens the validity of their analyses. Others have relied on sample data from select provinces, which may lack generalizability and fail to account for externalities, introducing biases stemming from local governance and diverse economic or political factors. Therefore, an empirical model is necessary to evaluate the impact of the national volume-based procurement policy and to investigate its spillover effects on substitute drugs.

II. Data

To assess the impact of centralized drug procurement, I utilized data obtained from the Chinese Pharmaceutical Database. This database provides extensive information on procurement time, drug name, dosage form name, formulation specification, whether selected, unit price, and procurement volume, covering the period from 2016 to 2022 across around 1,000 major public hospitals in China. The chosen hospitals are located across 24 provinces, excluding Tibet, Hainan, Gansu, Jiangxi, Guangxi, Ningxia, and Qinghai. The selected provinces are recognized for their abundant medical resources and are deemed representative of the pharmaceutical demand across most regions of the country. I select 18 therapeutic areas, covering anti-infection, cardiovascular and cerebrovascular systems, blood and hematopoietic systems, nervous system, anti-tumor, endocrine and metabolic regulation, and mental disorders. Under each disease category, I analyze at least 3 drugs (including centralized procurement products and substitute products) . The raw data has 28,215 entries.

III. Empirical Strategy and Results

The study is divided into two parts. The initial section employs a Difference-in-Differences (DID) methodology to examine the first round of centralized procure-

ment conducted in 2018. Subsequently, I employ a DID approach with multiple time periods to examine the impact of seven rounds of interventions.

A. Analysis of the 2018 Centralized Procurement

Methodology and Summary Statistics

To analyze the effect of 2018 centralized procurement, I use a DID model:

$$Y_{i,t} = \beta_1 + \beta_2 T_i + \beta_3 P_t + \lambda (T_i \times P_t) + \gamma X_{i,t} + \epsilon_{i,t} \tag{1}$$

where $Y_{i,t}$ represents the outcome of drug i in time period t, T_i is a dummy variable indicating whether the drug belongs to the centralized group (1 for centralized, 0 for non-centralized), P_t is a dummy variable indicating whether the centralized procurement policy has been implemented (0 for before, 1 for after), and $X_{i,t}$ denotes a vector of category fixed effects.

The three outcomes I studied are accumulated expenditures, accumulated quantity and unit price for every medication in quarters. Table2 presents some descriptive statistics of these three outcomes from the data at baseline. Although the differences between cumulative expenditure and quantity are large because of the market demand, the difference of average unit price is insignificant, which provides evidence for valid counterfactual. Additionally, the trend of these outcomes from 2016 to 2022 is further illustrated in Figure 2–4, which demonstrates distinct trends prior to and following the initial intervention in 2018.

Table 2—Summary Statistics

	Control (1)	Treatment (2)	Difference (3)
Expenditure	7,536,082	113,308,100	-105,772,018***
	(2206955)	(13948940)	(30989360)
Quantity	1,920,923	14,413,200	12,492,280***
	(5660821)	(18023840)	(4010083)
Price	37.77436	15.2058	22.5686
	(217.1351)	(31.448)	(10.624)
Observations	2952	80	

Note: This table shows the differences of outcomes between the procurement and non-procurement group at the beginning of the policy. Columns 1 and 2 present means with standard deviations in parentheses. Column 3 reports differences with standard errors in parentheses, clustered at each medicine. Statistical significance of differences denoted using *p < 0.10, **p < 0.05, ***p < 0.01.

Figure 2. Trend of Expenditures

Figure 3. Trend of Quantities

Results

Table 3 presents the findings of the DID model pertaining to the government centralized procurement of the year 2018. Compared to non-procurement medications, procurement medication expenditures have decreased substantially, the

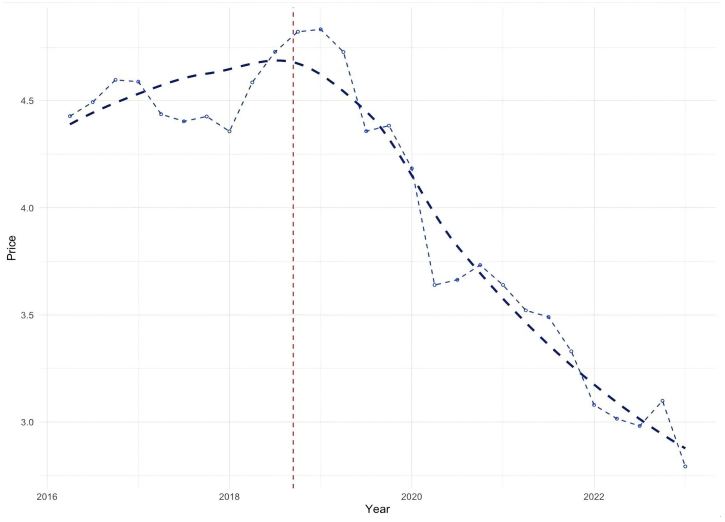

FIGURE 4. TREND OF PRICE

Note: These figures illustrate the progression of results from 2016 to 2022. The red line indicates the occurrence of the initial intervention. The red line denotes the point at which the initial intervention took place. The blue line represents the actual outcomes, while the black line illustrates the fitting of these outcomes.

quantity has increased, and the price has decreased significantly. This aligns with the objectives of the policy. The findings further suggest that it is justifiable to extend the policy from 11 experimental cities to encompass a broader region of the country.

The results demonstrate enhanced significance when utilizing category fixed effects. Among the diverse classifications of diseases, antidiarrheal medications and angiotensin-converting enzyme inhibitors emerge as the most substantial factors in the decrease of healthcare expenditures. Antihypertensive medications, anti-AIDS treatments, and antidiarrheal drugs play a crucial role in the reduction of quantity. Furthermore, antihypertensive medications, antidepressants, and non-steroidal anti-inflammatory drugs have significantly contributed to the decrease in prices. Nonetheless, for particular categories, including antiasthmatics and antidepressants, there is an evident rise in price subsequent to the intervention, which corresponds with the rising demand for these two types of medication in recent years. Consequently, the government's present focus on the acquisition of such medications is essential.

I subsequently employ the results obtained after logarithmic transformation in substitute of the original results for estimation, which distinctly illustrates the percentage of change. However, the importance of specific coefficients has waned, and their capacity for explanation has similarly diminished. Overall, expenditures experienced a reduction averaging -16,902,210 yuan, which repre-

sents approximately 24.88% of the total. The quantity experienced an increase of 3,278,841 units on average, which corresponds to an approximate rise of 12.33%. And the average price per unit experienced a decline of 2.4547 yuan, representing a reduction of approximately 37.22%. This observation indicates that following the implementation of the initial pilot centralized procurement policy, hospitals demonstrated a heightened tendency to employ centrally procured pharmaceuticals instead of non-centrally procured options. despite this, as a result of the government's involvement in price negotiations with pharmaceutical companies through contractual agreements, the overall financial burden on patients has been alleviated.

Table 3—Effects of the First Centralized Procurement

	Expenditure		Quantity		Price	
	(1)	(2)	(3)	(4)	(5)	(6)
$T_i \times P_t$	-16,902,210***	-16,902,210***	3,278,841***	3,278,841***	-2.4547***	-2.4547***
	(5,829,039)	(5,837,265)	(1,146,429)	(1,148,046)	(0.854)	(0.856)
T_i	105,803,000***	107,696,800***	12,485,570***	12,726,830***	-22.5357**	-16.8247
	(30,991,930)	(30,701,910)	(4,010,456)	(3,998,801)	(10.649)	(15.273)
P_t	1,012,148***	1,012,148***	186,248.4***	186,248.4***	-0.0987	-0.0987
	(222,735.5)	(223,049.8)	(36,476.07)	(36,527.54)	(0.2289)	(7.822)
Constant	7,505,074***	7,454,909***	1,927,628***	1,921,237***	37.7415***	37.5902***
	(812,268.3)	(816,364.3)	(208,843.7)	(204,962.7)	(8.030)	(7.822)
Observations	6,040	6,040	6,040	6,040	6,040	6,040
R^2	0.2047	0.2293	0.1044	0.1303	0.0003	0.0447
Category Fixed Effect	No	Yes	No	Yes	No	Yes

Note: The table reports the results of difference-in-difference estimation. Columns 2, 4, and 6 report the regression results with disease category fixed effect. Standard errors are in parentheses and clustered by medicine. Statistical significance of differences is denoted using *p < 0.10, **p < 0.05, ***p < 0.01.

Robustness Check

To ensure the robustness of the findings, the event study model proposed by Jacobson, LaLonde and Sullivan (1993) is employed. Figures 5–7 illustrate the trends in expenditures, quantities, and prices during the two periods prior to and the four periods following the implementation of the centralized procurement policy, along with 95% confidence intervals. The results reveal a substantial decline in expenditures, a significant increase in quantities, and a marked decrease in prices during the two post-policy periods. These trends align closely with the regression results, further reinforcing the validity of the findings and demonstrating that the initial phase of centralized procurement had a significant and reliable impact on all three outcomes. Additionally, the observed changes, combined with the relatively narrow confidence intervals, highlight the policy's effectiveness in achieving its primary objectives of reducing medication costs and improving accessibility.

I conducted a further examination of a critical assumption inherent in the

Table 4—Effects of the First Centralized Procurement (Log-Transformed Outcomes)

	In(Expenditure)		In(Quantity)		In(Price)	
	(1)	(2)	(3)	(4)	(5)	(6)
$T_i \times P_t$	-0.2488***	-0.2488***	0.1233	0.1233	-0.3722***	-0.3722***
	(0.065)	(0.065)	(0.088)	(0.088)	(0.046)	(0.04581)
T_i	3.8318***	3.7456***	3.5241***	3.2581***	0.3077	0.4874*
	(0.430)	(0.410)	(0.300)	(0.348)	(0.298)	(0.277)
P_t	0.1139***	0.1139***	0.1018***	0.1018***	0.0122**	0.0122**
	(0.026)	(0.026)	(0.026)	(0.026)	(0.006)	(0.006)
Constant	13.6413***	13.6436***	12.2632***	12.2703***	1.3781***	1.3733***
	(0.088)	(0.085)	(0.092)	(0.088)	(0.071)	(0.063)
Observations	6040	6040	6040	6040	6040	6040
R^2	0.0572	0.1202	0.0516	0.1286	0.0004	0.1980
Category Fixed Effect	No	Yes	No	Yes	No	Yes

Note: The table reports the results of difference-in-difference estimation with log-transformed outcomes. Column 2,4,6 report the regression results with disease category fixed effect. Standard errors in parentheses clustered by medicine. Statistical significance of differences denoted using *p < 0.10, **p < 0.05, ***p < 0.01.

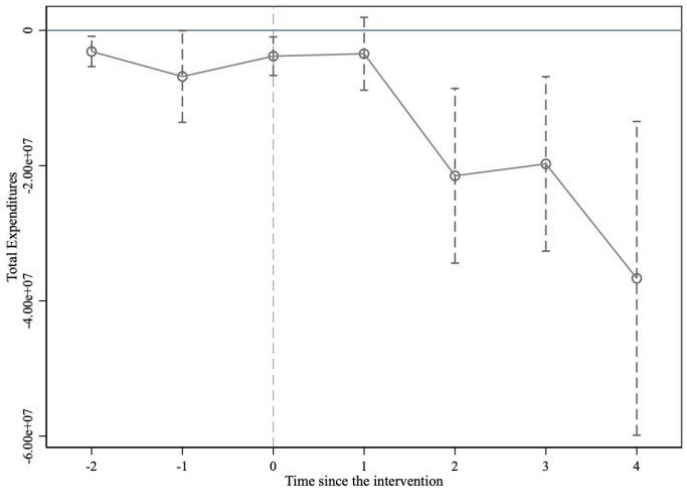

Figure 5. Trend of Expenditures for Procurement (2018–2019)

DID model—the parallel trends assumption—which posits that, in the absence of treatment, both the control group and the treated group would exhibit identical trends. In accordance with the hypothesis that "linear trends are parallel," the p-values for expenditures, quantities, and prices are 0.2596, 0.2673, and 0.5301, respectively. These values suggest that the parallel trends assumption cannot be rejected. Furthermore, Figures 8–11 present the observed means for both the procurement and non-procurement groups, facilitating a comparison of their linear

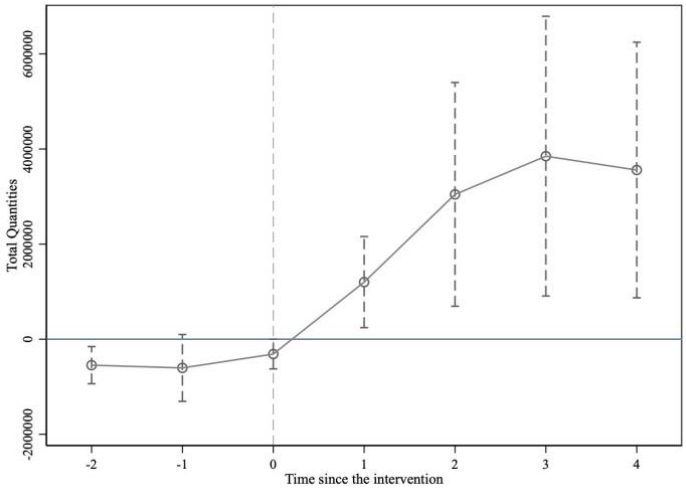

Figure 6. Trend of Quantities for Procurement (2018–2019)

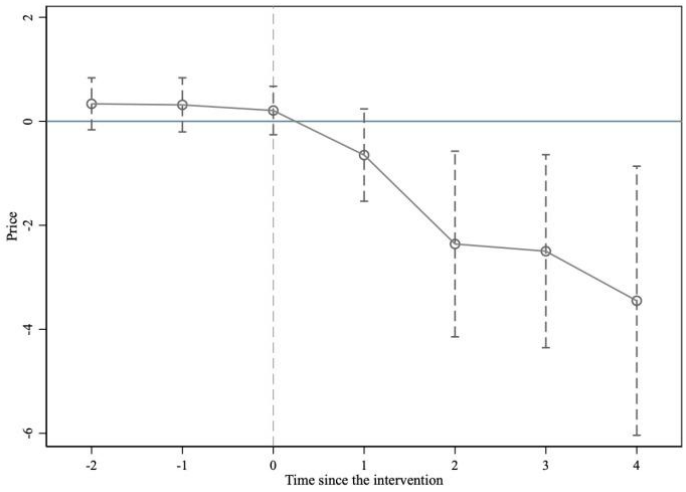

Figure 7. Trend of Price for Procurement (2018–2019)

Note: These figures illustrate the results of the event study, showing trends in the outcomes during the two periods before and the four periods after the implementation of the centralized procurement policy, with 95% confidence intervals.

trends. The outcomes demonstrate consistent trends prior to the implementation of the policy, followed by a notable divergence subsequent to its enactment. This observation substantiates the validity of the parallel trends assumption and

reinforces the robustness of the regression results.

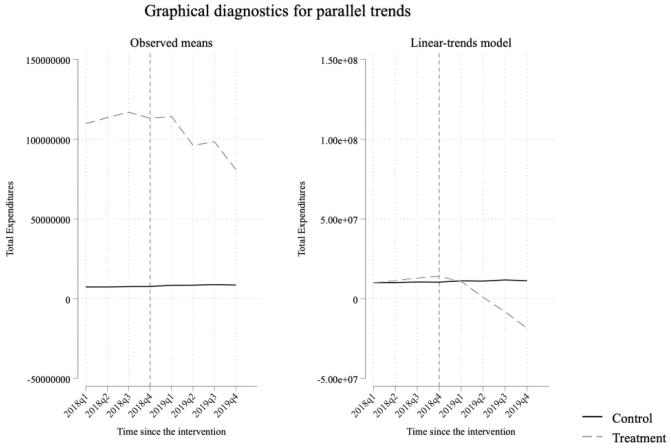

Figure 8. Expenditures Parallel Trends Diagnosis

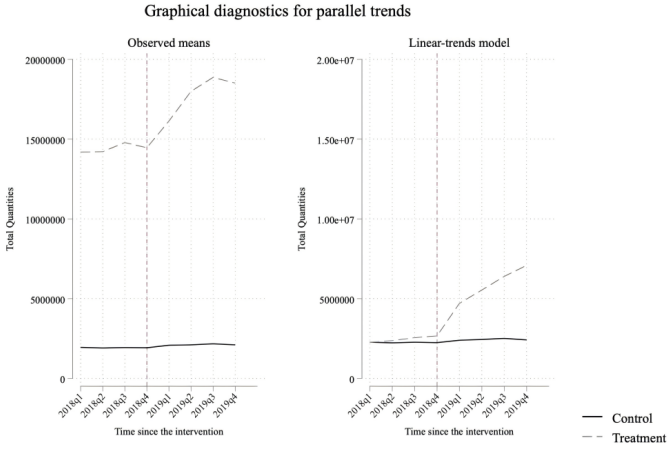

Figure 9. Quantities Parallel Trends Diagnosis

Meanwhile, I also analyzed the results using the Propensity score matching-difference in differences (PSM-DID) model introduced by Heckman, Ichimura and Todd (1997). I conducted matching according to specifications, formulations, and data categories, thereafter executing regression analysis.

As defined by Rosenbaum and Rubin (1983), the propensity score of a drug

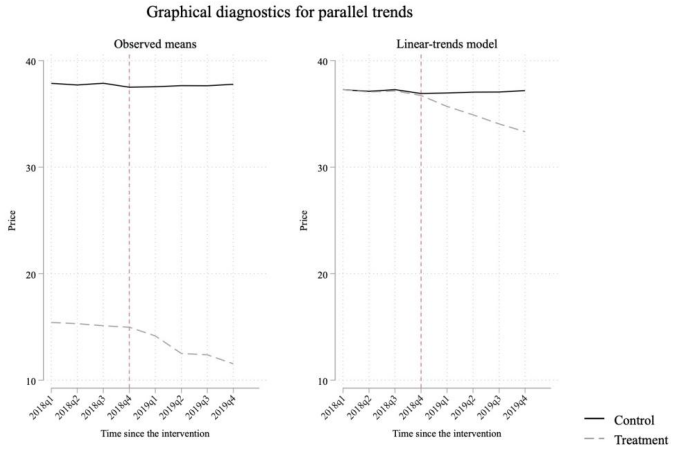

FIGURE 10. PRICE PARALLEL TRENDS DIAGNOSIS

Note: These figures provide a graphical diagnosis of the parallel trends assumption for the three outcomes. The left panel displays the observed means for the control and treatment groups, while the right panel presents the linear trend model, comparing the trends between the two groups.

obtaining therapy, given the multi-dimensional feature vector, is:

$$P(X) = Pr(T = 1 \mid X) \tag{2}$$

where T is a dummy variable indicating whether the drug belongs to the centralized group (1 for centralized, 0 for non-centralized), X denotes multi-dimensional feature vectors. This study employs the logit probability model to estimate conditional probabilities.

The regression analysis, derived from the equation in (1), is displayed in Table 5. Incorporating fixed effects for disease categories demonstrates statistically significant coefficients for all three outcomes, with especially notable decreases in expenditures and costs. When outcomes undergo logarithmic transformation, as demonstrated in Columns 2, 4, and 6, the results retain robustness and display substantial statistical significance. These findings are far more persuasive than the results presented in Table 4, when matching was not utilized. This contrast underscores the significance of propensity score matching in augmenting the robustness and reliability of predicted policy effects, hence reinforcing the validity of the results derived from the research.

The robustness checks indicate that the inaugural consolidated procurement strategy enacted in 2018 exhibited remarkable efficacy. The dataset utilized in this investigation, spanning from the first quarter of 2018 to the fourth quarter of 2019, provides two principal advantages that bolster the reliability of the results. Initially, as a robust panel dataset, it remains unaffected by the execution

Table 5—Robustness Check using Propensity Score Matching-Difference in Difference

	Expenditure	ln(Expenditure)	Quantity	ln(Quantity)	Price	ln(Price)
	(1)	(2)	(3)	(4)	(5)	(6)
$T_i \times P_t$	-18,214,150**	-0.2558***	3,237,373***	0.1062**	-2.6651***	-0.3620***
	(6,588,214)	(0.066)	(575,871.9)	(0.032)	(0.519)	(0.089)
T_i	153,309,800***	4.4218***	18,098,550***	3.7103***	-14.8429***	0.7115***
	(2,734,196)	(0.018)	(143,521.8)	(0.012)	(0.465)	(0.009)
P_t	1,683,674***	0.1202***	346,675.7***	0.1155***	0.0888	0.0047
	(306,039.7)	(0.025)	(38,093.49)	(0.024)	(0.087)	(0.003)
Constant	9,094,430***	13.7121***	5,283,171***	12.9693***	23.8926***	0.7428***
	(212,344.2)	(0.027)	(46,253.66)	(0.034)	(0.093)	(0.013)
Observations	5,752	5,752	5,752	5,752	5,752	5,752
R^2	0.4898	0.4032	0.3975	0.4002	0.0285	0.2816
Category Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table reports the results of propensity score matching-difference in difference estimation. Columns 2, 4, 6 show results of log-transformed outcomes. All columns report the regression results with disease category fixed effect. Statistical significance of differences denoted using *p < 0.10, **p < 0.05, ***p < 0.01.

of later centralized procurement strategies, guaranteeing that the observed impacts are exclusively ascribed to the initial round. Secondly, as the data were gathered before the COVID-19 pandemic, drug demand remained uninfluenced by pandemic-related factors, hence offering a more accurate representation of patients' standard medicine requirements and the policy's effects in usual conditions.

B. *Evaluation of Seven Rounds of Interventions*

Methodology and Summary Statistics

To evaluate the effect of seven rounds of centralized procurement, I utilize a difference-in-difference model with multiple time periods introduced by Brantly Callaway and Callaway and Sant'Anna (2021):

$$Y_{i,t} = \beta_1 + \beta_2 T_i + \beta_3 P_{i,t} + \lambda (T_i \times P_{i,t}) + \gamma X_{i,t} + \epsilon_{i,t} \tag{3}$$

where $Y_{i,t}$ represents the outcome of drug i in time period t, T_i is a dummy variable indicating whether the drug belongs to the centralized group (1 for centralized, 0 for non-centralized), and $X_{i,t}$ denotes a vector of category fixed effects. $P_{i,t}$ is a individual-specific treatment period dummy variable indicating whether the centralized procurement policy has been implemented for drug i in time period t (0 for before, 1 for after).

Table 6 presents the mean values and differences in expenditures, quantities, and prices between procurement and non-procurement drugs from 2016 to 2022. The differences are all statistically significant, which is partially attributable to

Table 6—Summary Statistics

	Control (1)	Treatment (2)	Difference (3)
Expenditure	5,811,921	48,267,580	42,455,660***
	(15,805,460)	(74,876,430)	(8,549,713)
Quantity	1,651,174	6,905,625	5,254,451***
	(5,314,949)	(9,137,504)	(1,076,182)
Price	43.2068	68.37015	25.1633***
	(300.844)	(348.646)	(47.975)
Observations	14,854	1,085	

Note: This table shows the differences of outcomes between the procurement and non-procurement groups from 2016 to 2022. Columns 1 and 2 present means with standard deviations in parentheses. Column 3 reports differences with standard errors in parentheses, clustered by each medicine. Statistical significance of differences is denoted using *p $<$ 0.10, **p $<$ 0.05, ***p $<$ 0.01.

the substantial disparities in observations between the control group and the treatment group. This disparity may adversely impact the integrity of the regression outcomes. Notably, the average price of drugs in the treatment group is significantly higher, indicating the objective of the centralized procurement policy to lower the costs of expensive medications. However, this necessitates additional investigation to ascertain if the government may attain comparable results by replacing high-cost procurement medications with lower-priced, therapeutically equivalent non-procurement alternatives.

Results

Table 7 displays the outcomes of the difference-in-difference estimation across several time periods. The examination of seven rounds of procurement indicates a decline in expenditures and prices, with both coefficients demonstrating significance following logarithmic transformation. In comparison to use data solely from the initial round of centralized procurement, the decreases in expenditures and prices are more significant, and the regression's explanatory strength is enhanced. Nonetheless, the regression coefficient for quantity is markedly negative, yet transforms to positive upon logarithmic transformation. The centralized procurement approach may lead to a fall in quantity, resulting in a significant decline in pricing, which might be ascribed to a general reduction in drug demand. This indicates that the model may overstate the policy's effect on prices.

Robustness Check

I continue to observe the trends in outcomes before and after the intervention using an event study approach, with the results presented in Figures 11 – 13. The

Table 7—Effects of Centralized Procurement (2016 - 2022)

	Expenditure	ln(Expend.)	Quantity	ln(Quantity)	Price	ln(Price)
	(1)	(2)	(3)	(4)	(5)	(6)
$T_i \times P_t$	-26,293,770***	-0.6611***	-1,286,752*	0.3253*	-27.5714	-0.9871***
	(5,463,621)	(0.156)	(658,750.2)	(0.169)	(21.2408)	(0.103)
Constant	10,953,910***	13.4594***	2,277,241***	12.0523***	44.8666***	1.4081***
	(260,016.7)	(0.007)	(31,350.28)	(0.008)	(1.011)	(0.005)
Observations	16,705	16,705	16,705	16,705	16,705	16,705
R^2	0.8347	0.8775	0.9138	0.8831	0.9403	0.9635
Individual and Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table reports the results of difference in difference estimation with multiple time periods. Columns 2, 4, 6 show results of log-transformed outcomes. All columns report the regression results with individual and time fixed effect. Statistical significance of differences denoted using *p < 0.10, **p < 0.05, ***p < 0.01.

execution of the policy shows diverse impacts on various results.

Figure 11 illustrates a modest rise in overall expenditures after the initial pilot of centralized procurement. However, following the nationwide expansion of the policy in the second quarter of 2019, spending started to decrease. Figure 12 shows that drug quantities rose following the initial pilot procurement but started to decline about a year later, ultimately dropping below the levels seen before the procurement. The variations in quantities are quite small. This trend can be attributed to a variety of factors: (1) Hospitals might have notably accelerated up their use of procurement drugs to adhere to the policy, causing an initial surge in quantities that eventually stabilized; (2) With the gradual roll out of the policy, certain high-cost, more effective, and lower-dosage drugs could have gained traction, leading to a general decrease in quantities. Figure 13 shows a minor reduction in drug prices after the initial pilot procurement. A significant decrease in price took place following the fourth round of centralized procurement in the first quarter of 2021.

In contrast to event studies that exclusively examine the effects of the initial pilot procurement, an analysis of outcomes across numerous procurement rounds indicates no significant changes immediately after each round. This may be ascribed to the narrower spectrum of procurement pharmaceuticals relative to non-procurement drugs. Moreover, the brief gaps between procurement cycles may have reduced the discernible effects. To resolve this, I optimized the selection of procurement drugs and produced the graphs depicted in Figures 14 - 16. These graphs exhibit analogous tendencies while offering a more lucid representation of the results.

IV. Conclusion

The experimental findings in this research indicate that centralized procurement markedly decreases costs and prices, however its effect on quantity remains ambiguous. Analysis of the initial round of policy implementation reveals an increase tendency in quantities; conversely, when data from all seven rounds is considered, a decreasing trend emerges. This aligns with the policy aims and outcomes from other studies, suggesting that the centralized procurement policy enhances patient access to affordable pharmaceuticals and fosters equity in healthcare.

The study also reveals that various drug kinds exhibit distinct responses to the centralized procurement regime. For several medicine categories, costs have increased rather than decreased following the policy's implementation. This paradox primarily manifests in pharmaceuticals experiencing substantial increases in market demand in recent years. Developing suitable centralized procurement policies tailored to the distinct attributes of various pharmaceuticals will be a primary emphasis for forthcoming policy execution and enhancement.

Nevertheless, the study possesses certain drawbacks. The external shock of the COVID-19 pandemic is expected to affect post-2020 data and may have amplified the apparent effects of the policy due to the increased demand for healthcare during this time. To resolve this issue, it is essential to concentrate on long-term trends in expenditures, service volume, and pricing, while considering the pandemic's distorting impacts. Moreover, substantial obstacles persist in obtaining full healthcare data in China, which hinders the assessment of the centralized procurement program. This study utilized generalized data for regression analysis, thereby constraining the depth of insights and the accuracy of its results.

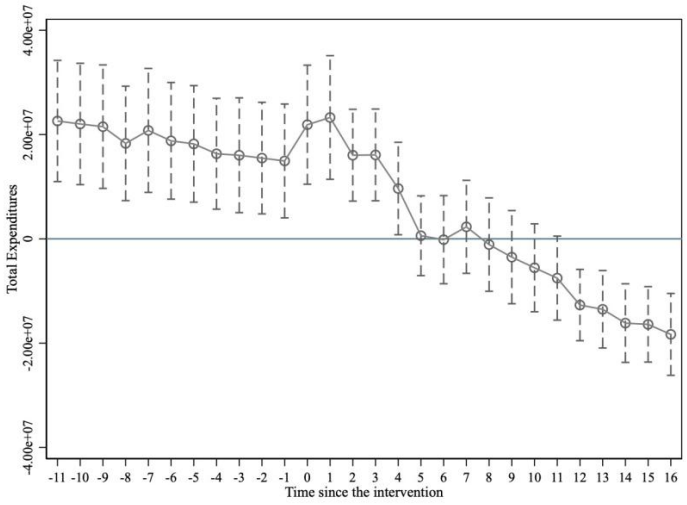

FIGURE 11. TREND OF EXPENDITURES (2016–2022).

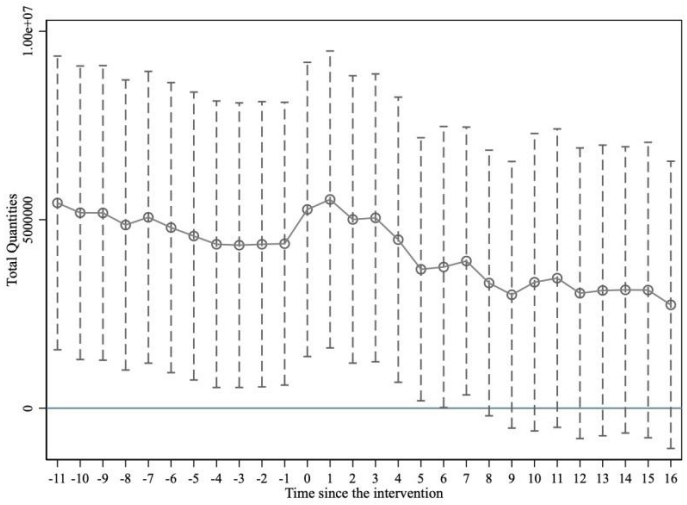

FIGURE 12. TREND OF QUANTITIES (2016–2022).

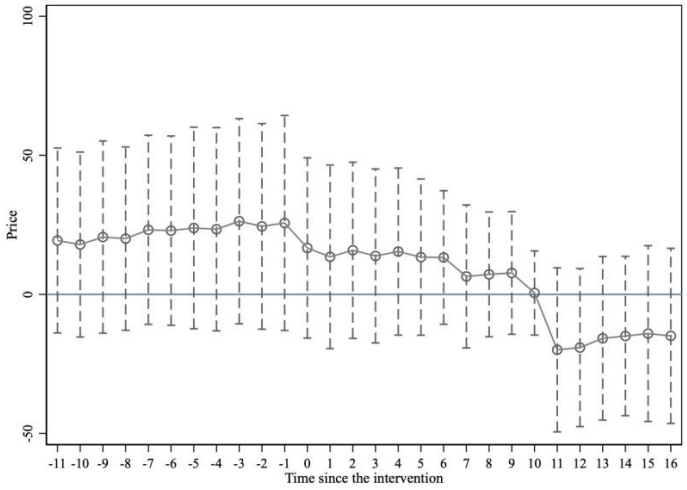

FIGURE 13. TREND OF PRICE (2016–2022).

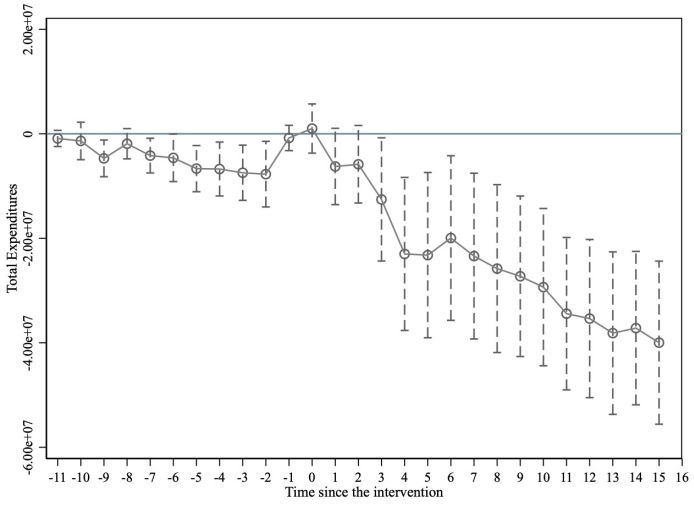

FIGURE 14. TREND OF EXPENDITURES FOR PROCUREMENT MEDICATIONS (2016 - 2022).

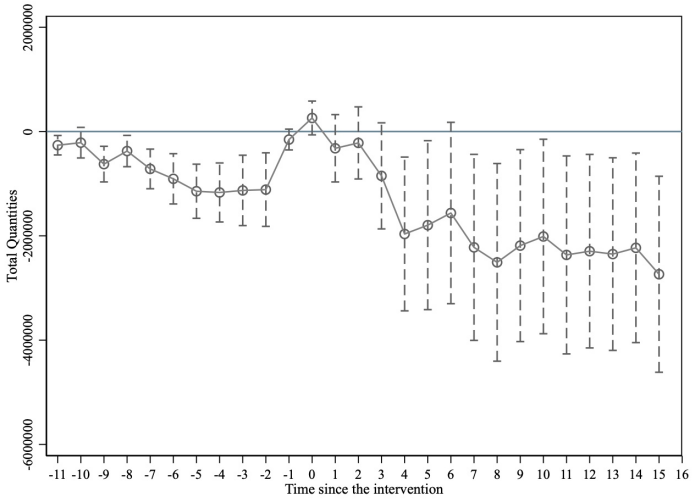

Figure 15. Trend of Quantities for Procurement Medications (2016 - 2022).

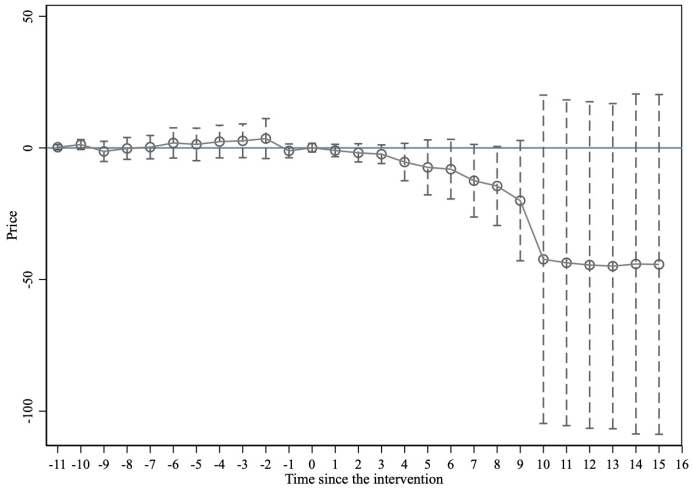

Figure 16. Trend of Price for Procurement Medications (2016–2022).

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