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When State Becomes the Only Buyer: Effects of national volume-based procurement of cardiac stents in China*

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Abstract

Medical device prices are a significant drivers of high healthcare spending in China; however, lowering prices remains an open question. We examine a unique solution for China as the central government acts as a single buyer for medical devices in the context of the national volume-based procurement (VBP) of cardiac stents. The tender held in November 2020 and reduced the average price of cardiac stents by 95%. Using detailed inpatient discharge record data, we found that the national VBP program increased patients' total medical spending by 20%. The failure in reducing medical costs was due to physician-induced demand; the utilization of coronary stents and drug-eluting balloons increased by almost 10%. Distortionary effects were more prominent for patients with residential insurance and physicians with higher persuasion power.

Keywords: National Volume-based Procurement, Supplier-induced demand, Physician incentives, heart attack management

JEL classification: I11, I13, L20

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1.Introduction

Sourcing healthcare expenditure has been a major public health policy concern in China over the past two decades. Healthcare spending increased from 4.7% of the GDP in 2008 to 6.2% in 2016 (Fu, Li and Yip, 2018). Some of these increases can be attributed to advancements in medical technology. High-value medical consumables such as coronary stents and artificial joints have been widely used. From 2009 to 2017, the number of percutaneous coronary interventions (PCIs) in China increased from 408,000 to 753,000, with an annual growth rate of 25%, which is almost four times the Organization for Economic Co-operation and Development (OECD) average (OECD 2011).

The rapid increase in utilization of high-value medical consumables in China is not unique. The OECD reports an annual growth rate of 13.6% in Spain and 14.6% in Sweden for angioplasty (OECD, 2011). High-value medical consumables are usually expensive, primarily because of asymmetric information and unbalanced market power (Grennan et al., 2013, 2014). Governments and policymakers are making significant efforts to reduce the market price of medical devices.

Although a large body of research has focused on the effects of price reductions owing to payment system reforms, there have been few attempts to evaluate the effects of price changes from procurement policies (Gruber, 1996; Yip, 1998; Dafny, 2005; Shigeoka and Fushimi, 2014; Clemens and Gottlieb, 2014; Coey, 2015). There exist some pertinent questions to be answered: Do hospitals in developing countries respond to the reduction in high-value medical consumable prices owing to government procurement policies? If governments exert buyer power and implement monopsonic interventions in price reduction, would these policies bring welfare improvements to patients? Few studies have addressed these issues because of the lack of reliable data or natural experimental settings to trace government monopsonic intervention in high-value medical consumable markets in developing countries.

This study focused on the national volume-based procurement (VBP) of coronary stents in China and studied its effects on reducing medical expenditure. In the national VBP, the government acted as a single buyer and negotiated on behalf of national public hospitals to reduce the price of coronary stents. The rationale is that through monopsony power, the government can bring down prices not only for the selected products but also eliminate the potential kickbacks that physicians receive from stent sales. Tendering was held on November 5, 2020, and the products were made available in public hospitals from January 1, 2021 onwards. National VBP has reduced the cost of coronary stents substantially from an average of 13,000 700 RMB per stent (China State Council, 2020). The national VBP provides the opportunity to conduct a regression discontinuity design (RDD) to estimate the impact of the government's monopsonic intervention in reducing high-value medical consumable prices on healthcare costs.

Using detailed inpatient discharge record data from public hospitals in two cities in central China, our RDD estimates reveal that the national VBP program did not reduce total medical expenditure for heart attack patients. The reduction in coronary stent prices caused negative income shocks for physicians. In response, physicians were likely to prescribe more stent surgeries owing to income effects and use more medical consumables other than stents because of substitution effects. The empirical results of this study confirm our hypothesis. We found a strong relationship between the decrease in stent prices from VBP and the increase in the volume of angioplasty surgeries. The implementation of VBP leads to an angioplasty surgery rate of 21.6 %. In addition, after the national VBP, the average number of coronary stents used in each surgery increased by 0.24. Moreover, we found strong evidence that physicians respond to negative income by increasing the usage of drug-eluting balloons (DEBs). The average number of DEB used in each surgery increased by 0.15 after the VBP.

The heterogeneous analysis was conducted as the following. First, we examined the effects of the patients' insurance types and found that physicians were more likely to prescribe stents and DEBs for patients with urban resident insurance and new cooperative medical scheme compared to patients with urban employee insurance. Second, we tested the effects of the program according to the hospital type. In China, heart attack treatments are usually performed at secondary and tertiary hospitals. Physicians at tertiary hospitals have greater persuasion power because tertiary hospital beds are inadequate. We found that physicians in both hospital types responded to the negative income shock from VBP by increasing the utilization of stents and DEBs. However, physicians at tertiary hospitals increased the rate of stent implantation and the rate of DEB implantation was substantially higher than that at secondary hospitals. On average, after the implementation of the national VBP, patients at tertiary hospitals receive 0.13 more stents per surgery and 0.14 more DEB per surgery. Our results suggest that physician-induced demand is more prominent for patients with generous insurance and physicians with higher persuasion power.

This study contributes to the literature by focusing on the effects of government procurement policies. Most studies in the literature concentrated on the effects of procurement policies on lowering prices and reducing firms' innovation (Duggan and Morton, 2010; Clemens and Rogers, 2020; Ding et al., 2021; Ji, 2023). However, few studies have examined the effects of procurement policies on patient outcomes. One exception is Duggan and Morton (2006), which examined how the Medicaid prescription drug purchasing policy affects the prices of non-Medicaid consumers.

Additionally, our study examines the effects of physicians' financial incentives on heart attack treatment. Numerous studies have discussed the relationship between physicians' financial incentives and the unnecessary use of coronary stent operations (Cutler, McClellan and Newhouse, 2000; Chandra and Staiger, 2007; Coey, 2015; Currie et al., 2016; Dunn and Shapiro, 2018). However, most of these studies were conducted in the US. To the best of our knowledge, this is the first empirical study to identify physician-induced demand for heart attack treatment in China.

Moreover, this study combines the broad empirical literature on physician agency with observational data (Gruber and Owings, 1996; Yip, 1998; Chalkley and Tilley, 2005; Clemens and Gottlieb, 2014; Shigeoka and Fushimi, 2014). Several studies examined the impact of physicians' financial incentives on prescription drug spending in China (Currie et al., 2011; Lu, 2014; Wu, 2018; Fang et al., 2021; Yang et al., 2021). For example, Wu (2018) found that physicians increased non-drug expenditures in response to decreasing drug prices while keeping total spending unchanged. Fang et al. (2021) found that a decrease in drug revenue led to an increase in non-drug spending.

The remainder of this paper is organized as follows: Section 2 introduces the institutional background and describes the conceptual framework. Section 3 describes the data considered for this study. Section 4 describes the empirical strategies. The results are presented in Section 6. Section 7 concludes the study.

2.Background

2.1 The national Volume-based Procurement Program

Before the implementation of the national VBP, high-value medical consumables were often purchased based on requests from doctors. Physicians would designate the product brands, models, and suppliers. The hospital procurement department could only follow the choices of the clinical doctors blindly because they did not understand the technical characteristics of medical consumables.

Procurement at the national level was first piloted in the National Centralized Drug Procurement (also known as the "4+7 tender trial"). Four municipalities (Beijing, Tianjin, Shanghai, and Chongqing), and seven sub-provincial cities (Shenyang, Dalian, Xiamen, Guangzhou, Shenzhen, Chengdu, and Xi'an) joined this tender. All the hospitals in the pilot cities were required to submit an agreed procurement volume for the listed drugs to the National Healthcare Security Administration (NHSA). The NHSA then organizes competitive bidding and price negotiations on behalf of the pilot cities based on the overall annual agreed procurement volume. The "4+7 tender trial" was successful, resulting in an average price reduction of 52% for the listed drugs (Yang et al., 2021).

Inspired by the initial success of the price reduction, the central government launched the national VBP for coronary stents in 2020 as the starting point for high-value medical consumables. This program intended to buy 1.07 million coronary stents starting in 2021, which constitutes nearly 70% of the total consumed coronary stents in 2019. The bidding was held on November 5, 2020, and ten varieties of coronary stents from eight companies won the bidding, including two American companies (Boston Scientific and Medtronic) and six Chinese companies. The average prices of the products dropped from RMB 13,000RMB to 700RMB. Most of the winning products were drug-eluting stents (DES), with only one drug-coated stent.

After the implementation of the VBP, public hospitals can purchase products that have won bids at respective prices. For other non-winning products, if their generic names were the same as those of the winning products, the purchase price would not be higher than the bid price. In other words, the VBP effectively limits the prices of coronary stent products in the market. The VBP prices have been in effect for all public hospitals in the two municipalities and 16 provinces since January 2021. For the research areas, new prices took effect in all public hospitals on January 1, 2021, providing a good opportunity to identify the impact of the national VBP with RDD.

2.2 Treatment of Heart Attack, Physician Income and Patient Health Insurance

Patients usually undergo one of three procedures for the treatment of a heart attack: Drug treatment, angioplasty, or coronary artery bypass graft (CABG). As CABG is a major open-heart surgical procedure, most public hospitals in China opt for drug treatment or angioplasty. During angioplasty, stents are typically used to reduce the probability of re-occlusion. Drug-eluting balloons (DEBs) can be used together with stents or separately, depending on the patients' conditions.

Physicians work as employees of hospitals in China. Their income usually consists of two components: A fixed-based salary and a variable component, which is the commission percentage of patient revenue generated by the department. Physicians' choices of coronary stents are heavily influenced by medical device firms (Grennan, 2013). While it is difficult to observe firm–physician interactions directly, various studies have documented that physicians often receive in-kind compensation, such as meals, gifts, or payments such as consulting fees and royalties (Grennan, 2014; Bergman et al., 2022).

China has three types of health insurance: Government-provided urban employment insurance, government-provided resident insurance, and private insurance. The two government-provided insurance types are exclusive, and private insurance can be purchased either in addition to government-provided insurance or on its own. An individual is eligible and mandated to take urban employment insurance if he works in a formal sector and holds an urban registration ("hukou" in Chinese). All other citizens — those with rural or urban registration, however, without a formal sector job are eligible for resident insurance.

High-value medical consumables were charged separately from other treatments before the introduction of the national VBP. The reimbursement rate was 80% for patients with urban employee insurance and 70% for those with resident insurance, with a cap of 8,000 RMB per stent. Under the national VBP, coronary stents are reimbursed together with other treatment procedures under the Prospective Payment System (PPS). High-value medical consumables, such as DEB, are still charged fee-for-service after the national VBP.

3. Data

The primary data source of this study is inpatient discharge records (IHD) between June 2018 and June 2021 from 68 public hospitals in central China. The IHD data provide detailed information on patients' accurate dates of admission, discharge, and surgery; primary and up to five secondary diagnoses; primary and up to seven secondary surgical procedures; 40 categories of medical expenditures; length of stay; 30-day readmission rate; and patient demographic characteristics such as age, gender, and insurance status. Given the complexity of heart attack treatment, all hospitals included in the sample were secondary or tertiary hospitals. We restricted our sample to patients aged 21 years and above. The final sample consisted of 134,889 inpatients.

The inpatient discharge record data provides the following advantages for this study: First, it contains precise and comprehensive information on patients' surgical treatments and utilization of stents and DEBs; second, it provides accurate information on the date of inpatient admission, avoiding measurement errors from patients' recall. These records provide essential information for our empirical identification and help measure patients' stents and DEB utilization accurately.

Table 1 provides the summary statistics for the sample. Column (1) presents the entire sample. Columns (3) and (5) indicate the results before and after the national VBP, respectively. For the entire sample, the average age of the heart attack patients was 70.3 years old, 47.2% were female, and more than 90% were married. Among the patients enrolled, the urban employee insurance and resident insurance groups were 34.5% and 58.5%, respectively. The average length of stay was 8.75 days and the 30-day readmission rate was 14.5%. The average total medical expenditure was 10651.9 RMB for a single inpatient stay. Approximately 30.3% of the patients received stent implantation and 19.6% received DEBs.

4.Empirical strategy

The main specification considers observations from January 1, 2021. We standardized the date of inpatient admission around January 1, 2021, as a percentage of the year. The econometric model estimated is:

$$Y_i = \alpha + \rho T_i + \gamma AD_i^k + \delta(T_i \times AD_i^k) + X'\beta + \varepsilon_i \quad (1)$$

where Y_i represents the outcome interest for individual i. T_i is a dummy for being admitted after January 1, 2021; and AD_i^k is the date of admission running variable of polynomial order k. X represents a set of control variables including a patient's age and its square, gender, marital status, number of other diseases, and insurance status. The parameter of interest is the coefficient ρ. The main specification included covariates and used a uniform kernel. The MSE-optimal bandwidth was calculated using the method described by Calonico, Cattaneo and Titiunik (2014). To explore the sensitivity of the choice of bandwidth, Table A.2 presents the estimates for the outcome variables that vary the bandwidths from 0.1 to 0.5 years.

As the tender was held on November 5, 2020, patients can gain information on price drops and manipulate their admission dates. If such behavior occurs, our RDD identification would be violated. Figure 1 depicts the density of the running variables for January 1, 2021. We observed that inpatient admissions were smooth across the cutoff. We conducted a donut-hole RDD in the robustness checks to test the potential influence of expectations. One noticeable feature of Figure 1 is a drop in inpatient admissions of approximately 0.15, where the Chinese New Year (CNY) occurs in 2021. We discuss the effects of the CNY on the estimation results in the robustness Section.

Before presenting the RDD results, we tested whether the controls were balanced. Table A.1 presents the balance tests using various covariates as dependent variables in Equation (1). All covariates were smooth at the cutoff, with no statistically significant estimates. Appendix C presents the falsification test on January 1, 2020, as the fake cutoff.

5.Results

We begin the analysis by presenting graphical evidence of the relationship between inpatient admission dates and utilization of medical devices. Panels A and B of Figure 1 illustrate the distribution of stent use before and after the cutoff. Panel A represents the stent utilization rate and Panel B indicates the average number of stents used per surgery. Dots represent the average rate of stent utilization on each date of inpatient admission, fitted lines indicate fitted values from the polynomial regression, and vertical lines indicate the cutoff points. In both figures, we can observe clear jumps in stent utilization after the cut-off value.

Figure 2 depicts the relationship between DEBs utilization and inpatient admission dates. Panel A presents the utilization of DEBs and Panel B describes the average number of DEBs used per surgery. Though the national VBP reduced the prices of stents, the prices of DEBs remain unchanged. Thus, prescribing more DEBs in stent surgery can increase physicians' income. Consistent with our hypothesis, we observe small but clear jumps after the cutoff for DEB utilization.

Table 2 presents the regression results with RDD estimates (Equation 1). Column 1 and column 2 indicate the estimates for stent utilization. At the external margin, the national VBP leads to an increase of 10.6 percentage points in stent utilization rate for patients with surgery treatment. At the internal margin, the implementation of the program results in 0.114 increase in average number of stents used per surgery. The magnitude of the increase is large, amounting to more than 37%. Columns 3 and column 4 indicate the results for DEB utilization. Similar to the utilization of stents, the national VBP leads to an increase of 10.3 percentage points for DEB utilization rate and 0.099 increase in average number of DEBs used per surgery. The magnitude of the increase is equal to more than 60% when compared to the mean value before the program. The empirical results suggest that physicians respond to the negative income shocks by increasing utilization of medical devices at both the external and internal margin.

As the national VBP substantially reduced stent prices, we were interested in checking whether the price reduction led to a decrease in medical expenditure. Table 3 presents the RDD estimates for medical spending. Columns 1 and 2 report the results for total spending and patients' out-of-pocket spending, respectively. Despite the price reduction, we found that the implementation of the national VBP failed to reduce medical costs. Total medical spending increased by 21.8%, and patients' out-of-pocket expenses increased by 19.3%. Columns 3–5 present the estimates of patients' surgical, drug, and examination spending. We found that among the three categories of medical expenses, surgery spending increased the most (more than 70 %) compared with the average before the program. As hospitals are prohibited from charging markups for drugs, we observed no effect on drug spending for patients. moreover, we found a significant increase in examination spending of more than 16%. Appendix B presents graphical representations of medical spending.

Although the national VBP is designed to address the rising medical costs of medical devices, its fundamental goal is to improve patient health status. We could not observe the patients' self-assessed health status or satisfaction with their medical care as we had access only to data from the medical records. Therefore, we selected to use indicators such as the 30-day readmission rate, number of 30-day re-admissions, and average length of stay per hospitalization to characterize the quality of hospital diagnosis and treatment. If patients have multiple readmissions within 30 days of discharge, it reflects, to some extent, the poor quality of diagnosis and treatment in the hospital. These indicators are widely used in health economics (Chandra et al., 2016). Table 4 presents the results of the breakpoint regression analysis. In comparison to the period before the implementation of the national VBP for coronary stents, there was a slight increase of approximately 0.3% in the 30-day readmission rate, a decrease of 0.05 in the number of readmissions, and an increase of 0.277 days in the average length of stay per hospitalization. None of these results were statistically significant. In a previous analysis, we found that doctors increased the probability of performing stent surgeries on patients after policy implementation. As a result, there may be a slight increase in the length of hospital stay and readmission rate. After the policy implementation, the number of readmissions as well as the in-hospital mortality rate decreased, indicating a slight improvement in healthcare quality from certain aspects. However, owing to the lack of statistical significance, these conclusions should be treated as mere references.

6 Heterogeneous effects

6.1 Heterogeneity analysis by insurance type

The traditional *physician-induced demand* model assumes that patients follow physicians' instructions blindly (McGuire, 1998). However, recent studies have proposed that physicians work more as persuaders, while patients are the actual decision-makers (Xiang, 2021). Based on patient characteristics, physicians use different strategies to convince patients.

From our previous analysis, we concluded that physicians responded to negative income shocks from the national VBP by increasing the use of stents and DEBs. We estimate Equation (1) separately for patients with urban employee insurance and residential insurance to check whether physicians target patients differently; and Table 5 presents the estimates. We found that patients with residential insurance were influenced more by the implementation of the national VBP. Compared to patients with urban employee insurance, those with residential insurance experienced larger increases in stent utilization, DEB utilization, and number of stents.

6.2 Heterogeneous analysis by hospital type

Hospitals in China are designated as primary, secondary, or tertiary institutions. Primary hospitals provide preventive care and rehabilitation services to small communities with no more than 100 beds. Heart attack treatments are typically performed in secondary or tertiary hospitals. Secondary hospitals have 100–500 beds and provide comprehensive treatment, and sometimes even specialist services. Tertiary hospitals have more than 500 beds and the highest level of medical capability. Services at tertiary hospitals are generally more expensive than those at secondary hospitals. However, there is a shortage of beds to meet patient demands. Thus, physicians at tertiary hospitals in China have greater persuasion power for patients than those at secondary hospitals.

We evaluated the effects of the national VBP according to hospital type. The estimated results are listed in Table 6. Physicians in both hospital types responded to the negative income shock from VBP by increasing the utilization of stents and DEBs. However, physicians at tertiary hospitals increased the rate of stent implantation to a greater extent than those at secondary hospitals. On average, after the implementation of the national VBP, patients at tertiary hospitals received 0.391 more stents per surgery and 0.294 more DEB per surgery. Regarding medical spending, patients at tertiary hospitals experienced a substantial increase in their total expenses. While patients in secondary hospitals also experienced an increase in total spending, the magnitude of the increase was much smaller than that in tertiary hospitals.

7. Robustness Tests

7.1 The "Chinese New Year effect"

One challenge in the RDD is that the Chinese New Year (CNY) follows shortly after January 1 every year. As the largest Chinese festival, patients and physicians tend to avoid hospitalization during CNY. As depicted in Figure 1, the density of the running variable and dates of inpatient admission run smoothly at the cut-off but fall sharply at around 0.15 in 2021, during the CNY. To eliminate the potential "CNY effect," we adopt an alternative specification by differencing out the discontinuity at neighboring years from January 1, 2021. We used 2020 as the neighboring year, although COVID-19 broke out in January that year[4]. For further robustness checks, we use 2019 as the neighboring year.

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[4] The reason why we selected 2020 is that the Chinese local governments continued social distancing policy to control mobility of the population in year 2021. Therefore, we believe the CNY effects are comparable between 2020 and 2021.

The regression discontinuity difference-in-differences (RD-DD) design is as follows:

$$Y_i = \alpha + \theta(Phase_i \times P_i) + \lambda\left(Phase_i \times AD_i^k\right) + \kappa\left(Phase_i \times P_i \times AD_i^k\right) + \varphi Phase_i + \mu P_i + \phi AD_i^k + \nu\left(P_i \times AD_i^k\right) + X'\beta + \varepsilon_i \quad (2)$$

where $Phase_i$ is a dummy with 1 being admitted between July 1, 2020, and June 1, 2021, and 0 being admitted at the same time in the neighboring year. P_i indicates whether the patient was admitted after the cutoff date (or the false cutoff date in the neighboring year). AD_i^k is the date of admission of the running variable of polynomial order k. The remaining specifications are the same as those in Equation (1). Furthermore, we include a set of dummies for admission year and month, hospitals, and cities. The parameter of interest is θ.

Table 7 presents the results with the neighboring year being 2020. The signs and significance of the results are consistent with the baseline RDD estimates. However, the magnitudes are slightly larger. In other words, the existence of "CNY effect" biased the estimates. Therefore, we interpret our RDD estimates as the lower bound of the true effects.

The individuals may have reduced their mobility around CNY in 2020, as COVID-19 broke out during that time. The "CNY effect" in 2020 may be larger in the year 2020 as compared to other years. We considered 2019 as the neighboring year, differencing the RDD estimates around January 1 between 2021 and 2019 to check the robustness of our results,. Table A.3 presents the regression results. These estimates are consistent with both the RDD and RD-DD estimates for 2020. The magnitudes are even larger than those for 2020 as the neighboring year. The results confirmed that the "CNY effect" might attenuate the true effects, causing our baseline estimates to be the lower bound.

7.2 Expectation effect

One of the primary concerns of our research was the potential expectation regarding the cutoff date. As the tender was held on November 5, 2020, the tendered products were available only after January 1, 2021, an individual may anticipate receiving less expensive stents after the cutoff date. In Figure 1, we plotted the density of the running variables and depicted that inpatient admissions were smooth across the cutoff. We followed Barreca et al. (2011) and conducted a donut-hole RD-DD regression to address this issue by excluding 15 days around the cutoff date. Panel A of Table A.4 presents the regression results. These estimates are similar to the baseline results. Particularly, the magnitudes of the coefficients were comparable to the baseline results. This reduced significance may have resulted from the reduced number of observations around the cutoff.

In addition to the policy expectations, patients may postpone their surgery to celebrate CNY. We employed donut-hole regressions around the CNY in 2021 to eliminate the "CNY effects." Panel B of Table A4 reports the regression results. The estimates are comparable to the baseline results, suggesting the robustness of the estimation.

8. Conclusion

Medical device prices are significant drivers of high healthcare spending worldwide. Effective reduction of these prices remains an open question. In this study, we evaluated the national VBP for cardiac stents in China by exploiting the implementation schedule of the program, all of which were available in all public hospitals from January 1, 2021, onwards. We adopted both RD and RD-DD designs to address the endogeneity problem.

This study has two primary findings: First, we found that the national VBP program led to a significant increase in physician-induced demand for coronary stents and drug-eluting balloons after the program. Second, despite the drastic reduction in stent prices after the program, the average prices of cardiac stents dropped by 95%, and the national VBP program increased patients' total medical spending by 20%. The distortionary effects were more prominent among physicians in tertiary hospitals with less competition.

This study has important policy implications: While government-led central procurement programs could effectively lower the prices of medical devices, total medical spending could not be controlled without considering physicians' financial incentives. The results imply that this program should be taken as an opportunity to promote a series of related policy reforms, including the Physician Payment System and compensation mechanism in hospitals, to mobilize the enthusiasm of physicians and guarantee the implementation of government-led central procurement programs.

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Tables

Table 1. Summary Statistics

	All		Before the VBP		After the VBP	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Total medical spending	10651.87	14617.87	10632.94	14719.76	10729.01	14195.22
Out-of-pocket spending	5394.87	8505.32	5314.43	8730.10	5725.72	7501.52
Surgery spending	1751.56	5980.92	1571.06	5769.27	2486.89	6725.43
Drug spending	2358.50	3480.52	2347.79	3379.12	2402.11	3865.99
Examination spending	2318.91	1988.57	2271.88	1945.67	2510.48	2143.96
Rate of stent implantation	0.30	0.46	0.30	0.46	0.31	0.46
Rate of DEB implantation	0.20	0.40	0.16	0.37	0.29	0.45
Avg. number of stents per surgery	0.31	0.48	0.31	0.48	0.32	0.48
Avg. number of DEBs per surgery	0.20	0.42	0.16	0.38	0.30	0.49
Mortality rate	0.00	0.06	0.00	0.06	0.00	0.06
Age	70.32	11.19	70.61	11.10	69.15	11.48
Female	0.47	0.50	0.47	0.50	0.48	0.50
Married	0.90	0.30	0.89	0.31	0.90	0.29
Number of other diagnoses	5.88	2.69	5.76	2.72	6.36	2.48
% of Urban Employee Insurance	0.35	0.48	0.35	0.48	0.32	0.47
% of Resident Insurance	0.59	0.49	0.58	0.49	0.62	0.48
Number of inpatient admissions	4.71	4.63	4.57	4.40	5.37	5.55

Note: This table presents means and standard deviations of the analysis sample between 2018 and 2021. N = 134,889 for full sample (column 1-2), N = 108,193 for sample before the VBP, and N = 26,696 for sample after the VBP.

Table 2. RDD estimates for medical device utilization

	Whether implanted any stent	Number of stents	Whether implanted any DEB	Number of DEBs
	(1)	(2)	(3)	(4)
National VBP	0.106***	0.114***	0.103***	0.099***
	(0.021)	(0.022)	(0.022)	(0.025)
N	36454	36454	36454	36454
Mean	0.298	0.306	0.162	0.165

Note: The table presents results of RD estimations. The results use local linear regression with a uniform kernel. Each regression includes controls for age, age square, gender, marital status, and number of other diagnoses. MSE-bandwidth calculated separately for each RD regression.

Table 3. RDD estimates for medical expenditure

	Total medical spending	Out-of-pocket spending	Surgery spending	Drug spending	Examination spending
	(1)	(2)	(3)	(4)	(5)
National VBP	2139.850***	1028.285***	1151.820***	194.471	356.897***
	(588.518)	(215.216)	(174.912)	(139.211)	(99.468)
N	134910	130846	134910	134910	134910
Mean	10632.94	5314.43	1571.06	2347.79	2271.88

Note: The table presents results of RD estimations. The results use local linear regression with a uniform kernel. Each regression includes controls for age, age square, gender, marital status, and number of other diagnoses. MSE-bandwidth calculated separately for each RD regression.

Table 4. RDD estimates for Quality of Care

	(1) 30-day readmission rate	(2) Number of readmissions	(3) Inpatient mortality rate	(4) Length of Stay
National VBP	0.003	-0.054	-0.000	0.277
	(0.014)	(0.048)	(0.003)	(0.324)
N	50638	50638	48698	49774

Note: The table presents results of RD estimations. The results use local linear regression with a uniform kernel. Each regression includes controls for age, age square, gender, marital status, and number of other diagnoses. MSE-bandwidth calculated separately for each RD regression.

Table 5. RDD estimates for patients with different insurance

	(1) Whether implanted any stent	(2) Number of stents	(3) Whether implanted any DEB	(4) Number of DEBs	(5) Total medical spending
Panel A. Patients with Urban Employee Insurance					
National VBP	0.049	0.048	0.027	0.003	178.673
	(0.062)	(0.066)	(0.063)	(0.067)	(1386.428)
N	3441	3441	3441	3441	9861
Panel B. Patients with Residential Insurance					
National VBP	0.110**	0.110**	0.130***	0.117**	1661.315**
	(0.047)	(0.048)	(0.050)	(0.050)	(824.990)
N	5517	5517	5517	5517	18643

Note: The table presents results of RD estimations. The results use local linear regression with a uniform kernel. Each regression includes controls for age, age square, gender, marital status, and number of other diagnoses. MSE-bandwidth calculated separately for each RD regression.

Table 6. RDD estimates for different hospital type

	(1)	(2)	(3)	(4)	(5)
	Whether implanted any stent	Number of stents	Whether implanted any DEB	Number of DEBs	Total medical spending
Panel A. Secondary hospitals					
National VBP	0.240***	0.253***	0.159***	0.158***	361.385
	(0.064)	(0.066)	(0.055)	(0.056)	(845.236)
N	23560	23560	23560	23560	107338
Panel Tertiary hospitals					
National VBP	0.367***	0.391***	0.230***	0.294***	7576.107**
	(0.092)	(0.096)	(0.087)	(0.095)	(3029.169)
N	12893	12893	12893	12893	25897

Note: The table presents results of RD estimations. The results use local linear regression with a uniform kernel. Each regression includes controls for age, age square, gender, marital status, and number of other diagnoses. MSE-bandwidth calculated separately for each RD regression

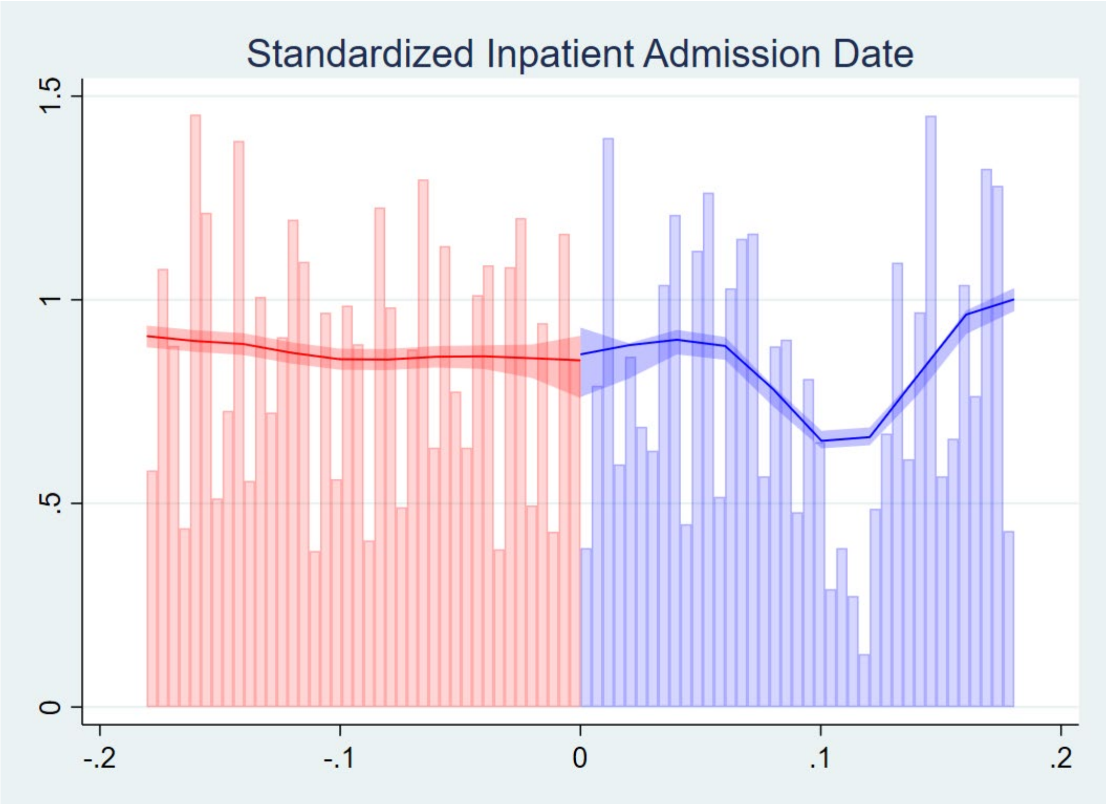
Table 7. RD-DD estimates

	Whether implanted any stent	Number of stents	Whether implanted any DEB	Number of DEBs
	(1)	(2)	(3)	(4)
National VBP	0.279***	0.296***	0.184***	0.204***
	(0.053)	(0.055)	(0.047)	(0.049)
R-square	0.058	0.058	0.105	0.105
N	26939	26939	26939	26939

Note: The results of the RD-DD model use January 1st, 2020 as the fake cutoff date. Each regression includes controls for age, age square, gender, marital status, and number of other diagnoses. The RD-DD regressions also control for year and month fixed effects, and hospital fixed effects. The regressions use a 0.6 year as the baseline bandwidth.

Figures

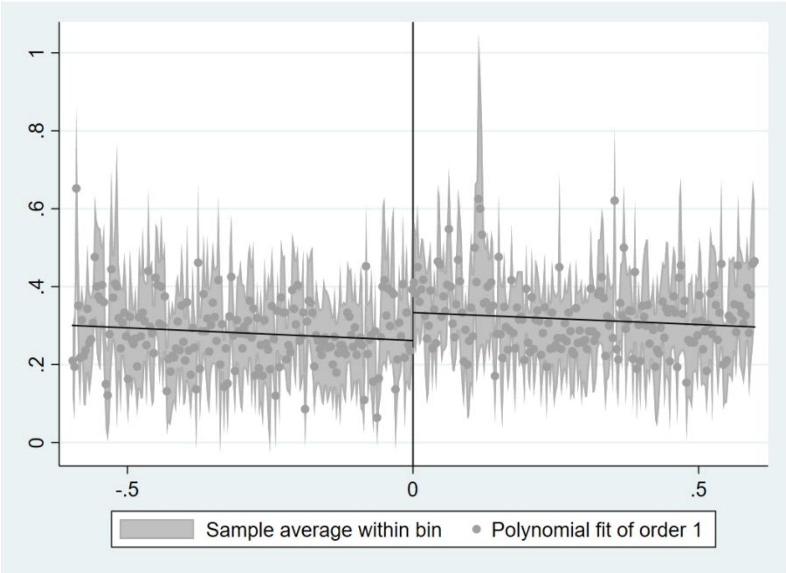
Figure 1. Density of the Inpatient Admission Date



Note: The figure presents the distribution of inpatient admission dates before and after the cutoff date. The x-axis represents the standardized dates with 0 being January 1st, 2021. The positive values represent dates after the cutoff and the negative values represent dates before. The standardization is done as percentage of a year.

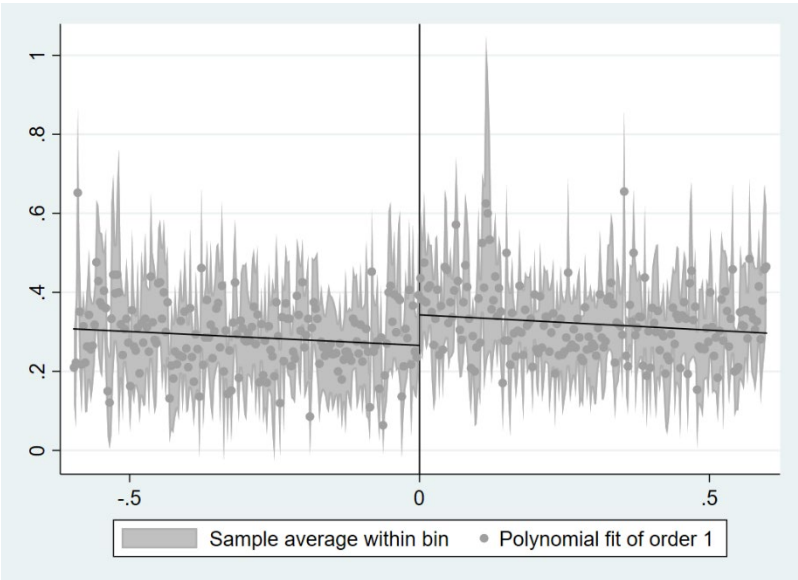
Figure 2.

Panel A. Stent Utilization Rate



Note: The figure presents the average percentage of stent utilization per day. The x-axis represents the standardized dates with 0 being January 1st, 2021. The positive values represent dates after the cutoff and the negative values represent dates before. The standardization is done as percentage of a year.

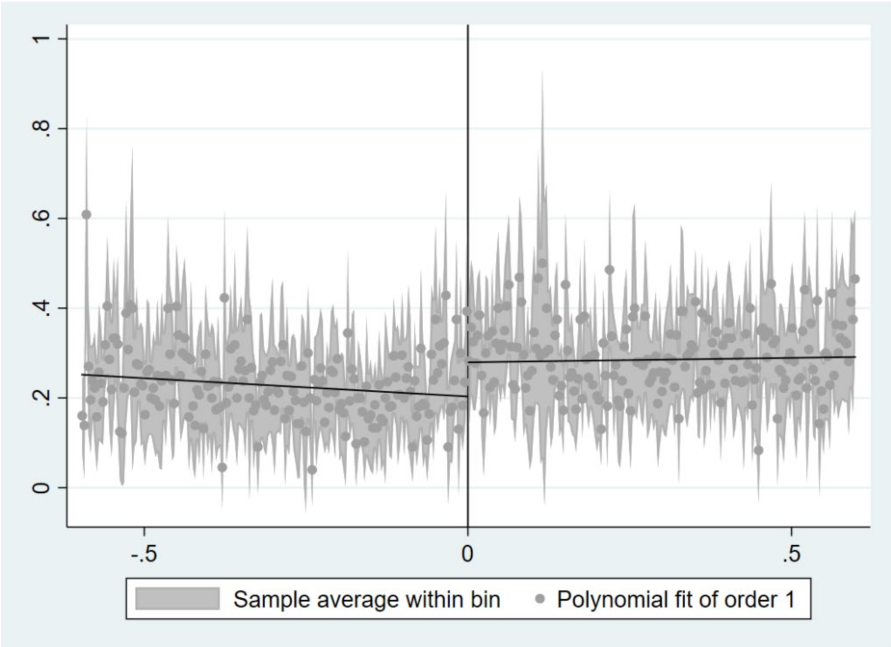
Panel B. Average number of stents used per surgery



Note: The figure presents the average number of stents used per surgery. The x-axis represents the standardized dates with 0 being January 1st, 2021. The positive values represent dates after the cutoff and the negative values represent dates before. The standardization is done as percentage of a year.

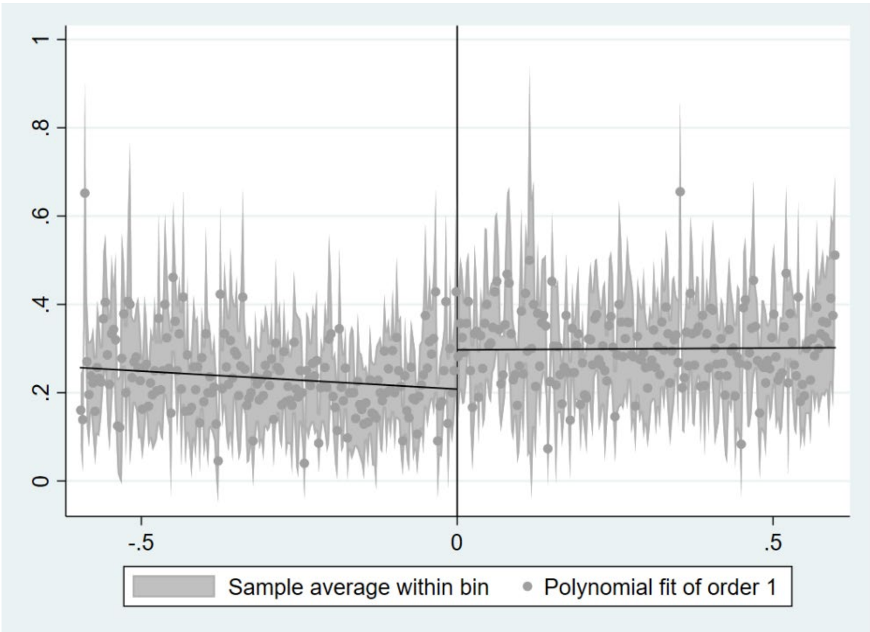
Figure 3.

Panel A. Drug-eluting Balloon Utilization



Note: The figure presents the average percentage of DEB utilization per day. The x-axis represents the standardized dates with 0 being January 1st, 2021. The positive values represent dates after the cutoff and the negative values represent dates before. The standardization is done as percentage of a year.

Panel B. Average number of drug-eluting balloons used per surgery



Note: The figure presents the average number of drug eluting balloons used per surgery. The x-axis represents the standardized dates with 0 being January 1st, 2021. The positive values represent dates after the cutoff and the negative values represent dates before. The standardization is done as percentage of a year.

Appendix

Appendix A.

Table A.1 Balance Test

	(1)	(2)	(3)	(4)
	Age	Female	Married	Number of other diagnoses
National VBP	0.087	-0.009	0.002	0.050
	(0.197)	(0.009)	(0.005)	(0.038)
R-square	0.054	0.013	0.129	0.286
N	51478	51401	49980	51479

Note: This table presents RD-DD estimation results of covariates using January 1st, 2021 as cutoff.

Table A.2 Variation of results by different bandwidth

	Bandwidth				
	+/- 0.1	+/- 0.2	+/- 0.3	+/- 0.4	+/- 0.5
Whether implanted any stent	0.153**	0.167***	0.077**	0.081**	0.080**
	(0.074)	(0.051)	(0.038)	(0.034)	(0.034)
Number of stents	0.171**	0.175***	0.086**	0.084**	0.080**
	(0.078)	(0.053)	(0.039)	(0.035)	(0.035)
Whether implanted any DEB	0.010	0.079*	0.039	0.062*	0.065**
	(0.082)	(0.045)	(0.036)	(0.033)	(0.031)
Number of DEBs	-0.007	0.070	0.046	0.052	0.065**
	(0.089)	(0.051)	(0.038)	(0.035)	(0.032)
Total medical spending	3114.618**	3045.476**	2526.083**	2995.369***	2512.213***
	(1518.432)	(1284.582)	(1150.844)	(1051.684)	(887.808)
Out-of-pocket spending	2671.635***	1498.569**	1668.176***	1673.283***	573.695*
	(821.239)	(638.487)	(557.624)	(527.116)	(345.798)
Surgery spending	103.074	94.271	69.982	62.887	64.577
	(119.716)	(89.823)	(54.038)	(50.182)	(49.834)

Table A.3 RD-DD estimates with year 2019 as the neighboring year

	(1)	(2)	(3)	(4)	(5)
	Whether implanted any stent	Number of stents	Whether implanted any DEB	Number of DEBs	Total medical spending
National VBP	0.533***	0.551***	0.252**	0.279**	7087.704***
	(0.138)	(0.142)	(0.116)	(0.123)	(1788.621)
R-square	0.058	0.058	0.118	0.116	0.164
N	24399	24399	24399	24399	86737

Note: The results of the RD-DD model use January 1st, 2019 as the fake cutoff date. Each regression includes controls for age, age square, gender, marital status, and number of other diagnoses. The RD-DD regressions also control for year and month fixed effects, and hospital fixed effects. The RD-DD regressions use a 0.6 year as the baseline bandwidth.

Table A.4 Expectation effects

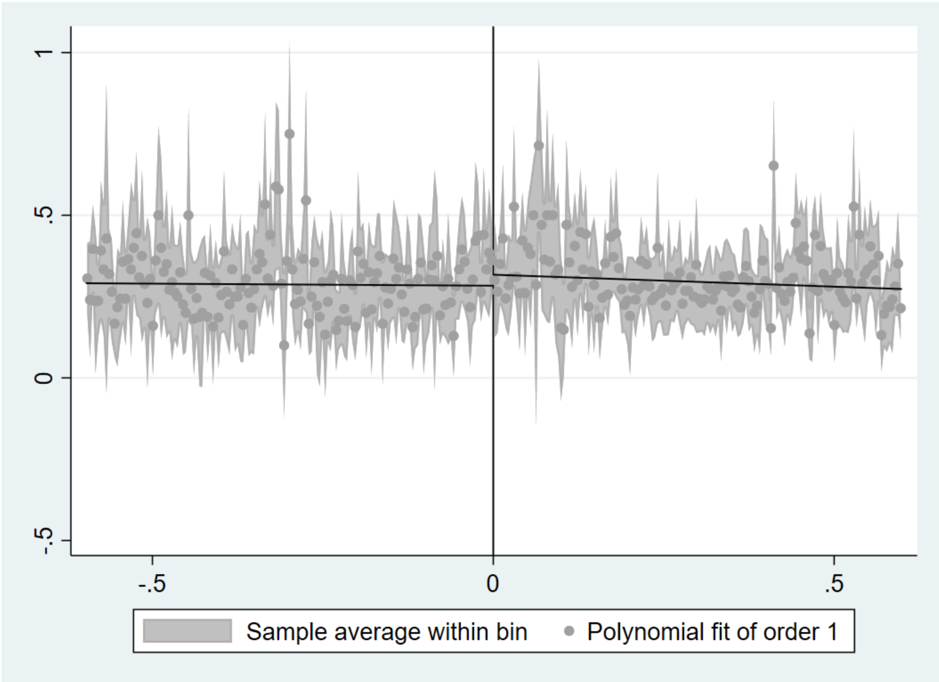
	(1)	(2)	(3)	(4)	(5)
	Whether implanted any stent	Number of stents	Whether implanted any DEB	Number of DEBs	Total medical spending
Panel A. Donut hole RD-DD estimates around January 1st, 2021					
National VBP	0.241***	0.257***	0.163***	0.197***	1797.683*
	(0.056)	(0.058)	(0.050)	(0.052)	(927.904)
R-square	0.057	0.057	0.103	0.102	0.156
N	24552	24552	24552	24552	80128
Panel B. Donut hole RD-DD estimates around CNY in 2021					
National VBP	0.253***	0.269***	0.178***	0.196***	918.997
	(0.054)	(0.056)	(0.048)	(0.051)	(888.291)
R-square	0.058	0.058	0.104	0.104	0.157
N	26023	26023	26023	26023	84236

Note: The results of the RD-DD model use January 1st, 2020 as the fake cutoff date.

Each regression includes controls for age, age square, gender, marital status, and number of other diagnoses. The RD-DD regressions also control for year and month fixed effects, and hospital fixed effects. The RD-DD regressions use a 0.6 year as the baseline bandwidth.

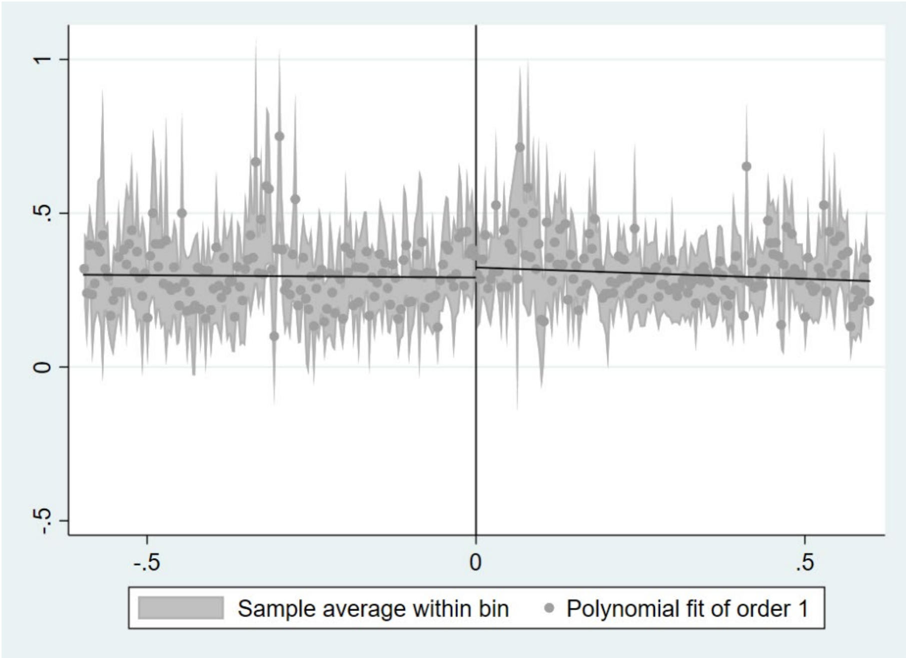
Appendix B. Falsification tests

Figure B.1 Stent utilization around January 1st, 2020



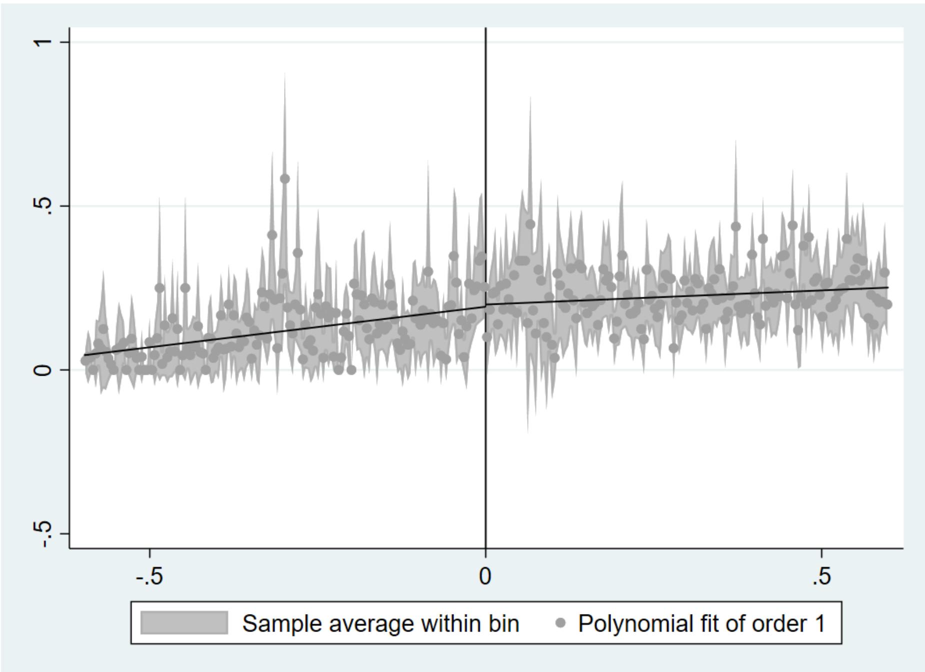
Note: the x-axis represents the standardized inpatient admission date around January 1st, 2020.

Figure B.2 Average number of stents used per surgery around January 1st, 2020



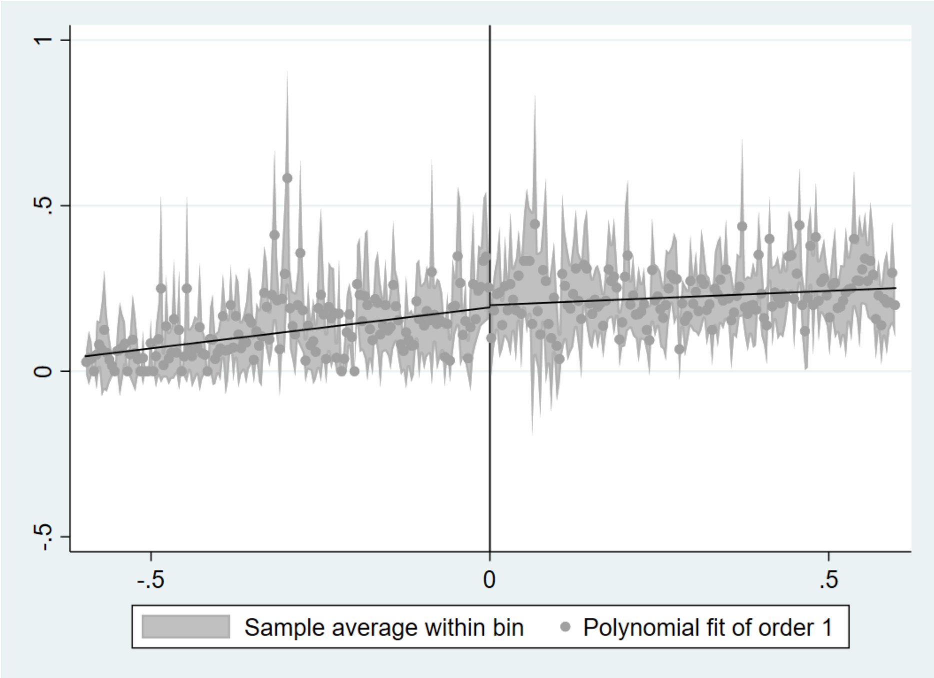
Note: the x-axis represents the standardized inpatient admission date around January 1st, 2020.

Figure B.3 DEB utilization around January 1st, 2020



Note: the x-axis represents the standardized inpatient admission date around January 1st, 2020.

Figure B.4 Average number of DEBs used per surgery around January 1st, 2020



Note: the x-axis represents the standardized inpatient admission date around January 1st, 2020.