

An Investigation of Marketing Compensation in Medicine: The Impact of the Information Disclosure Regulations

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Abstract

Pharmaceutical scandals frequently occupy national media headlines, and these controversial practices exacerbate the healthcare expenditure burden and cause ethical concerns. Big Pharma's marketing strategies involve making various types and sizes of payments to healthcare providers to induce favorable prescribing behaviors for their drugs. Enacted in 2013, the Physician Payments Sunshine Act (PPSA) mandates company disclosures of payments to physicians. Its effectiveness has been explored in various settings, but there have been few rigorous academic studies, and a unified conclusion has not been reached. In this paper, we utilized unique datasets, including pre- and post-PPSA payment data from six major pharmaceutical companies, to examine the impact of state-level disclosure policies and the federal PPSA on pharmaceutical companies' payments to physicians. Difference-in-difference analysis was adopted to study the dynamics of company payments to physicians before and after the PPSA. We found significant interactions for the state policies and the PPSA on all studied payment types for the six companies. The companies generally decreased their total payments to physicians and the number of paid physicians. However, the policy impacts differed across the payment types and companies.

Keywords: *information transparency; disclosure law; Physician Payments Sunshine Act; Open Payments; detailing; prescribing behavior; difference-in-difference; policy efficacy*

1. Introduction

The ultimate goals of the healthcare industry are to develop safe, affordable, and effective (efficacious) medicines; make medicines widely accessible to patients; and help patients lead longer, healthier lives. Unfortunately, this noble field has been filled with scandals and a constant plethora corruption case investigation. The EpiPen and Daraprim scandals are only the tip of the iceberg [3]. These life-saving

measures had outrageously high prices, and the high cost of Daraprim left thousands of cancer patients without access to this treatment. The notorious opioid war is still claiming an average of 46 lives each day in the United States, and a similar situation is happening with Novartis, which is currently under investigation for paying millions in kickbacks to doctors to influence their prescribing behavior [29]. These scandals have caused Americans to ponder how the healthcare system could enable such unethical conduct.

Furthermore, this type of misconduct inevitably contributed to the skyrocketing healthcare expenditures in the United States, along with low levels of patient trust and sub-optimal healthcare services. The Centers for Medicare & Medicaid Services (CMS) estimated that national healthcare spending increased from \$3.6 trillion in 2018 to \$3.81 trillion in 2019, and spending is expected to increase to \$4.01 trillion in 2020; furthermore, healthcare spending as a percentage of the gross domestic product (GDP) is projected to rise from 17.7% in 2018 to 19.7% in 2028 [36].

Concerns over the influence of pharmaceutical companies' sales promotion efforts on physicians surged around the 2000s with the rise of opioid war and multiple Big Pharma lawsuits. Since 1994, such concerns, which include legal, ethical, and economical aspects, have led quite a few states to enact laws requiring pharmaceutical manufacturers to disclose spending details about marketing targeted at medical practitioners. Minnesota was the pioneer of this movement in 1994, followed by Vermont (2002), West Virginia (2004), the District of Columbia (2004), Maine (2006), and Massachusetts (2009) [14]. Eventually, unified country-wide reporting and the disclosure of interactions between physicians and the pharmaceutical industry were mandated in August 2013 through the federal Physician Payments Sunshine Act (PPSA).

The PPSA requires healthcare product manufacturers (drugs, devices, biologicals, or medical supplies) to report payments to physicians and teaching hospitals that are over \$10 and other transfers of value to the U.S. Department of Health and Human Services. The goal of the PPSA is to create transparency and an accurate picture of the nature and extent of financial

relationships between physicians, teaching hospitals, and manufacturers. Three major reporting categories—general, research, and ownership and investment interest payments—and detailed sub-categories were developed. Data is made available to the public through the CMS Open Payments website (<https://openpaymentsdata.cms.gov/>). Passed with the hope of providing considerably more transparency to the healthcare field, PPSA has great potential to enable medical stakeholders to manage financial conflicts of interest, build patient trust, and guide the interactions among pharmaceutical companies and physicians to achieve optimal detailing, promote ethical conduct, and realize better patient care.

More than six years have passed since the first PPSA data collection period in 2013, and the impact of the policy is still unclear. Sturgis [34] in the ZS Executive Summary of the AccessMonitor™ and AffinityMonitor™ stated that the number of pharmaceutical sales representatives (reps) was significantly reduced from 101,800 in 2005 to about 60,000 in 2012 to 68,400 reps in 2017. In the same study, physicians became more reluctant to meet sales reps; 80% of the physicians were accessible to sales reps in 2008 but only 46% were in 2017. However, these changes have not led to a reduction in total payments to physicians per the CMS Open Payments data. A comprehensive study by Schwartz and Woloshin [32] revealed that marketing spending in the healthcare industry increased by 169% from 1997 to 2016. Direct-to-consumer (DTC) advertising and promotional events aimed at healthcare professionals were the two major promotional channels, and the latter had the most promotional spending, amounting to roughly \$20.3 billion in 2016 [32].

The PPSA was established to provide transparency regarding pharmaceutical payments to physicians and to deter payments and promote ethical conduct. Previous research (e.g., [4, 5, 15, 16, 19, 22]) on the PPSA's impact has approached the question from several angles and presented very diverse findings due to the complexity of the issue. To understand the PPSA's impact, researchers must consider multiple stakeholders, various fields of medicine, and the dynamics among physicians, pharmaceutical companies, hospitals, patients, and policy makers. To our knowledge, no studies have been conducted using a well-established model to investigate how companies adapted their payment strategies in light of the adoption of the PPSA. We believe that understanding company responses to the PPSA—the focus of the present study—is crucial for the success and effectiveness of the PPSA. Furthermore, identifying these actions through well-defined models could provide insights into the

efficacy of the policy and guide future government interventions.

The selection of the present study topic was motivated by the Big Pharma scandals, the associated ethical concerns in the healthcare industry, and the threat to patients' access to effective treatments, especially to life-saving drugs. Our investigation focuses on a major part of the pharmaceutical marketing tactics: payments made to physicians. A lawsuit settlement led to the creation of a payment database by ProPublica, providing us with the opportunity to conduct a pre- and post-analysis of the PPSA policy. We conducted our research at the company and state levels and investigated the detailed dynamics of company marketing strategies aimed at physicians before and after the adoption of the PPSA. In fact, the adoption of the PPSA serves as a natural experiment, enabling us to use the difference-in-difference (DID) analysis model to compare states that had PPSA-like policies before the PPSA was adopted and those that did not. We have utilized the DID model to reveal policy impacts before and after the adoption of the PPSA, specifically in terms of interactions among the State and PPSA policies and the payment strategies of six Big Pharma companies.

Our research is the first study to focus on and explore the PPSA policy impact at the company level and investigate firm behaviors, specifically related to marketing strategy dynamics by examining three of the general payment categories: meals, travel, and consulting. Furthermore, using three dependent variables—total payments to physicians, number of paid physicians, and payment per paid physician—we have been able to uncover individual firms' specific reactions to the PPSA, shed light on the impact of the PPSA on Big Pharma's drug promotion spending strategies, and offer insights to policy makers on the efficacy of the policy.

Through our DID model analysis, we identified the PPSA's impact on company payment strategies. First, companies' total payments to physicians (hereafter total payments), were either unchanged after the adoption of the PPSA or indicated a decreasing trend. These trends were consistent across payment categories. Second, the number of paid physicians was either stable or indicated a decreasing trend. Third, several of the researched companies increased the payment per paid physician, but decreased total payments and the number of paid physicians. Interestingly, the companies' payment per paid physicians after the adoption of the PPSA presented a full spectrum, as some reduced it, some raised it, and others stayed the same. Fourth, we observed quite different payment dynamics across all six studied companies. Fifth, the most common identified theme involved reductions in total payments and the number of paid physicians but increases in the

payment per paid physician. Even though policy makers will be pleased to see the reductions in the first two variables, the elevated payment per paid physician should cause concern as it might indicate a well-crafted selection mechanism through which a company only interacts with opinion leaders and influences the medical community in a subtle way.

The rest of the paper includes the following: 1) a review of the literature on pharmaceutical marketing and promotion, include detailing and general payments to physicians, and their influence on prescribing behavior, ethical issues related to pharma-physician interactions, and the impact and efficacies of the PPSA; 2) a description of the data used in this study and the empirical analyses conducted; 3) a description of the company- and state-level analysis and a presentation of the DID interaction results; 4) a description of the robustness test and the validation of the results; and 5) extensive discussions on firm strategies and recommendations for future research.

2. Literature Review

In this section, we first present the literature on ethical guidelines, regulations and concerns for medical practitioners, and then examine the informative and pervasive roles of the pharmaceutical company's marketing strategies involving both detailing and general payments to physicians. Next, we zoom in to focus on the PPSA policy and present the literature's diverse findings on the impact of those payments on physicians' attitudes toward manufacturers and prescribing behavior. Lastly, recent studies on the impact and efficacy of the PPSA policy are discussed.

The public perception of ethical issues in the pharmaceutical industry is largely negative; drug safety, pricing, data disclosure, marketing restrictions, DTC advertising, and pharmaceutical fraud are among the most prominent issues [35]. Cases about Vioxx, Bextra, and opioids showed a lack of ethical responsibility toward patients on the part of some pharmaceutical companies and suggested the existence of a serious degree of deception and a lack of integrity. The conflicts of interest among healthcare professionals and the pharmaceutical industry led to several regulations, such as the American College of Physicians and the Accreditation Council for Continuing Medical Education's guidelines on physicians' interactions with drug companies, the Pharmaceutical Research and Manufacturers of America's code of conduct, and the Office of the Inspector General of the Department of Health and Human Services' guidelines for drug manufacturers. Furthermore, prosecutors have used a body of federal laws dealing with fraud and abuse to

punish pharmaceutical companies and physicians involved in misconduct [35].

Equipped with data and analytics tools, sales reps can perform their job more effectively. Based on a 2001 analysis, the estimated return on detailing was 2:1 overall and 10:1 for new brand name drugs [26]. Elliot [11] (p.330) described: "One study found that for drugs introduced after 1997 with revenues exceeding \$200 million a year, the average return for each dollar spent on detailing was \$10.29. That is an impressive figure. It is almost twice the return on investment in medical-journal advertising, and more than seven times the return on DTC advertising." These marketing "successes" raised public concern about the conflict of interest relationship between physicians and their patients.

Pharmaceutical marketing contains two main categories: promotion to medical professionals and DTC advertising. The former includes detailing and various types of payments offered to the medical professionals. Academic fields have a long record of investigating these marketing effects. Detailing occurs when a pharmaceutical sales rep visits and attempts to persuade doctors to prescribe his/her company's products, and it includes the rep's doctor office visit, and the offering of free medicine samples, etc. Pharmaceutical company payments to physicians, made in forms of speaking engagement, travel reimbursement, meals for events, consulting opportunities, research grants, etc., might also have impact on physician's attitude and prescribing behavior toward the company. In the present study, we focus on companies' general payments (i.e., meals, travel, and consulting) to physicians. These payments are monitored based on the PPSA regulation, and the disclosure of the information is intended to positively affect the interactions between pharmaceutical companies and physicians.

Researchers from various disciplines, such as the medical, marketing, economics, and legal fields, have sought insights into the impacts of promotional activities toward physicians, which has generally played both informative and persuasive roles. Physicians have been shown to largely view pharmaceutical sales reps as important sources of information (Patwardhan, 2016), especially for rural area doctors whose peer interactions are limited [1]. Manchanda and Honka [25] conducted an integrative review of the effects of detailing and found that most perceptual research confirmed the important persuasive role of detailing in all stages of a drug life cycle on physicians' prescribing behavior both positively and significantly. Fickweiler et al. [12] also found that interactions among sales reps and physicians likely contribute to the irrational prescribing of the drugs promoted by the reps and called for interventions in the form of policies and education about the

implications of such interactions. Meanwhile, some researchers found that the persuasive impact of detailing, though significant and positive, was almost negligible [8, 33]. For example, Datta and Dave [8] found that detailing had a significant and positive effect on the number of new scripts written for the detailed drug albeit with an elasticity magnitude of merely 0.06. In light of detailings' negligible persuasive role and important informative role, Ching and Ishihara [6] cautioned policy makers that putting restrictions on detailing that was mainly informative in nature might reduce innovation and potentially lower patient welfare.

Researchers also studied the impact of industry payments on physicians' prescribing behavior and presented varied findings regarding ethical concerns. Dana and Loewenstein [7] showed that large gifts had more visible commercial influence, but small gifts were also influential. Patwardhan [28] showed that small gifts of \$20 were associated with higher prescribing rates. Jones and Ornstein [22] found that physicians in five common medical specialties who accepted at least one industry payment were more likely to prescribe brand name drugs at high rates than their counterparts. Grennan et al. [15] found that, on average, company payments to physicians led to a 73% increase in the prescribing of the focal drug, and these payments generally decreased the total consumer surplus.

Some researchers remained unconvinced about the positive relationship between promotions and prescriptions [7, 18, 31]. Carey et al. [5] offered another perspective, noting that, on average, doctors who received payments prescribed higher quality drugs for their patients. They also found that patients whose prescribers received payments from a pharmaceutical firm tended to have higher expenditures on that firm's drugs. In addition, they found no difference between prescribers receiving payments and those who did not on transition from prescribing brand name drugs to generics after patent expiration. It is interesting to mention that doctors were in agreement about the helpfulness of sales reps but almost never admitted that industry gifts made a difference in their prescribing decisions [11].

Although academics have diverse findings and opinions on whether pharmaceutical company payments significantly influence or swing physicians' prescribing behavior and negatively impact patient care, policy makers are determined to make pharmaceutical company payments to physicians transparent in order to induce more ethical conduct and build a better healthcare system. Since PPSA reporting began, studies have identified both positive and negative firm responses to the policy. Brunt [4] found that industry transfers to physicians have declined since public reporting was implemented, although transfers are still

significantly associated with increased prescription costs, brand name drug prescriptions, and the prescribing of high-risk medicines. Other researchers found similar results [9, 13].

However, Grolach and Pham-Kanter [14] (p.319) predicted some potential negative firm responses, noting that "Increased data accessibility generates incentives for firms could cut back on gifts and obvious marketing-related payments, which are likely to cause the most public uproar; on the other hand, firms could respond by under-reporting payments or misclassifying payments into non-reportable categories, leaving actual payments unchanged." These potential responses could abate the efficacy of the PPSA and are worth further examination. Meanwhile, Jones and Ornstein [22] examined the CMS Open Payments data from 2013 and 2014 and found that several of the nation's largest pharmaceutical companies dramatically reduced their payments to physicians for promotional speeches, attributing this action, at least in part, to increased transparency and heightened public scrutiny of such relationships. Related to information transparency and disclosure, Guo et al. [17] employed a DID research design to study the effect of the payment disclosure law introduced in Massachusetts in 2009, finding that the law resulted in a decline in prescriptions; however, the effect was highly heterogeneous across physician groups. Guo et al. [17] were among the first to study the causal impact of information disclosures on company payments and found that, on average, monthly payments declined by 2% due to the disclosures. However, heterogeneity in the treatment effects was also identified, and they found that a decline in payments was quite limited for well-sold drugs and among popular physicians.

Various parties have taken advantage of the CMS Open Payments data to better assist their decision making. Litman [24] found that medical centers screen their employee prescribers to verify potential financial conflicts of interest to reduce risks to these centers; granting agencies verify the financial relationships of grant applicants with the Pharmaceutical industry to evaluate their qualifications; government agencies screen the potential financial conflicts of interest of government employees; and attorneys are more informed about medical malpractice in order to better argue cases. Meanwhile, Easley [10] found that journal editors and reviewers are better informed about the connections among the authors and pharmaceutical companies for the submitted clinical trial research. However, patients in general are still largely under-informed [19].

Based on the previous literature, we are assured of the correlation between detailing and persuasion and the existence of the potential prescribing bias from industry

payments to physicians. These connection and potential bias present opportunities for ethical misconduct and might lead to a lower consumer surplus and suboptimal patient care due to the various parties' conflicts of interest. Thus, in this paper, we take the first step in exploring the PPSA's effectiveness in achieving its goals. We believe that the overall efficacy of the PPSA depends upon the dynamics of the intertwined reactions among its three major stakeholders: manufacturers, physicians, and patients. By investigating Big Pharma's marketing strategies, we can further understand the dynamics of the PPSA intervention in the healthcare field.

3. Data and Model-Free Analysis

We obtained data on payments made by pharmaceutical companies from two main sources: ProPublica's Dollars for Docs database and the CMS Open Payments database. Pharmaceutical company payment data from 2010 to 2013 was collected from ProPublica, a non-profit organization that gathers information on payments to prescribers made by 17 major pharmaceutical companies, as disclosed by those companies due to lawsuit settlements made before the PPSA was enacted. ProPublica's Dollars for Doctors database contains about 3.36 million payment records for \$4 billion paid medical providers and healthcare institutions in categories, such as consulting, education, meals, research, speaking, and travel.

Pharmaceutical company payments to physicians from 2014 to 2018 were obtained from the CMS Open Payments website. Established since the first PPSA collection period of August 2013, Open Payments is a national disclosure program that collects and publishes information about financial relationships between the healthcare industry (i.e., drug and medical device companies) and providers (i.e., physicians and teaching hospitals). All payments reported in the Open Payments system are classified into 15 categories (e.g., food and beverage, travel and lodging, and research). Since PPSA reporting started toward the end of 2013, capturing only four months of payment data, we decided to use ProPublica's data for 2013 since it captured payments for all 12 months.

To construct a compatible dataset of payments made by companies from 2010 to 2018 from the two data sources with more than 15 different reporting formats/categories, we first filtered the data by completeness and accuracy and then matched the categories from each company's self-reporting data to the PPSA's standard categories. Company selection was first based upon ProPublica's data availability, as not all companies reported in all categories in the selected time

period of 2010–2013. Missing data categories in various years were observed across companies. In order to include an equal number of years in the DID model, we omitted 2018 from our dataset. Meanwhile, as ProPublica's data was gathered based on a court order but no reporting template was given to the companies, each company developed its own categories according to its accounting records. Some payment categories from certain companies were either too ambiguous or too broad to be used in comparison with the standardized categories defined by PPSA; those companies were excluded from our dataset.

Eventually, six companies with complete and comparable datasets were included in our study—AstraZeneca, Eli Lilly, GlaxoSmithKline (GSK), Merck, Novartis, and Pfizer—and three compatible and relatively unambiguous reporting categories were chosen: meals, travel, and consulting. To ensure the validity of the research, speaking category was excluded since most companies reported speaking payments under various categories in the ProPublica dataset. The selected companies are part of Big Pharma in the United States, and all of them were on the ProPublica's top 10 list of companies that are most engaged with physicians (defined by the number of interactions between the company and doctors), with Pfizer and AstraZeneca topping the list [21]. Thus, we believe that our sample is a good representative of the pharmaceutical companies in the United States and can demonstrate the PPSA policy impact well.

To study the impact of the PPSA on company payment behavior, we applied the DID method at the state level [2]. We aggregated the state-level data on payments to prescribers based on the zip codes of the physicians' offices. Before the PPSA, six states/districts had PPSA-like state legislation requiring companies to report payments to prescribers: the District of Columbia (DC), Maine (ME), Massachusetts (MA), Minnesota (MN), Vermont (VT), and West Virginia (WV). Thus, these states formed the control group for our analysis. To select six comparable states to create the treated group, we used the following criteria: geographical proximity, state population, state GDP, number of active physicians, and number of active patient care physicians per capita. Thus, Maryland (MD), New Hampshire (NH), New York (NY), Wisconsin (WI), Rhode Island (RI), and Kentucky (KY) were selected (Table 1). In summary, our dataset contained annual payments on meals, travel, and consulting from 2010 to 2017 made by the six companies in each of the 12 states. We converted all payment amounts to 2013 dollars using inflation indices to make the payments from different years comparable. Figure 1 shows the aggregate payments of all six companies in the meals, travel, and consulting categories. The overall payments showed an

upward trend with meals demonstrating a slightly downward trend, travel a slightly upward trend, and consulting an upward trend.

Table 1. 12 Selected States in This Study

	Control Group	Treated Group
1	Washington DC	Maryland (MD)
2	Maine (ME)	New Hampshire (NH)
3	Massachusetts (MA)	New York (NY)
4	Minnesota (MN)	Wisconsin (WI)
5	Vermont (VT)	Rhode Island (RI)
6	West Virginia (WV)	Kentucky (KY)

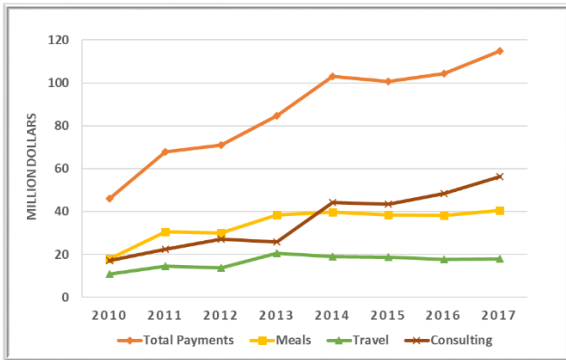


Figure 1. Six Companies' Total Payments by Categories in 50 States

In our DID analysis, we managed our uneven data series in the following ways. Given the missing data in the *before* PPSA data, we encountered uneven pairs in the *before* and *after* comparisons. Most companies had a longer *after* PPSA data series (four years) than a *before* PPSA series (ranging from one to four years). We ran an uneven DID model for the data from all years and a DID model for 2012–2013 (*before*) vs. 2014–2015 (*after*) for companies that had a short *before* PPSA data series. Meanwhile, to balance the sample, for a company missing one state's payment data, we removed the payment data from that state and its counterpart. For example, if Eli Lilly had no consulting payment entry for VT for 2013, so we excluded the payment data for both VT and RI for all years before running the DID for consulting for Eli Lilly. Thus, we included payment data from the same set of states for the *before* and *after* PPSA data series.

4. Company State-level Analysis on the PPSA Policy Impact

The enforcement of country-wide reporting in late 2013 based on the PPSA, the existence of six states with PPSA-like policies before the PPSA was adopted, and the availability of payment data before the PPSA through ProPublica provided us with a unique

opportunity to apply the standard DID method to evaluate the impact of the PPSA on company payment strategies at the state level. We analyzed the impact of the PPSA on each company, as well as on the aggregate payments of all six companies. For each company, we ran DID regressions for each selected payment category (meals, travel, and consulting), as well as a combined meals & travel category. Three dependent variables that could capture and reveal a company's marketing (i.e., payment) strategy were established: *total payments*, *number of paid physicians*, and *payment per paid physician* for each category for each state i in year t . The *number of paid physicians* refers to the unique number of physicians being paid, and the *payment per paid physician* is calculated as the average payment per uniquely paid physician. The following DID models were estimated, where M denotes meal, T denotes travel, and C denotes consulting:

$$\log \left(\begin{matrix} \text{PaymentOnMeals}, \text{PaymentOnTravel}, \\ \text{PaymentOnConsulting}, \text{PaymentOnMT} \end{matrix} \right)_{it} = \mu_i + \tau_t + \beta_1 \text{NoStatePolicy}_i + \beta_2 \text{NoStatePolicy}_i \times \text{AfterPPSA}_t + \epsilon_{it} \quad (1a)$$

$$\log \left(\begin{matrix} \text{PaidPhysicianCntOnM}, \text{PaidPhysicianCntOnT}, \\ \text{PaidPhysicianCntOnC}, \text{PaidPhysicianCntOnMT} \end{matrix} \right)_{it} = \mu_i + \tau_t + \beta_1 \text{NoStatePolicy}_i + \beta_2 \text{NoStatePolicy}_i \times \text{AfterPPSA}_t + \epsilon_{it} \quad (1b)$$

$$\log \left(\begin{matrix} \text{PayperPhysicianOnM}, \text{PayperPhysicianOnT}, \\ \text{PayperPhysicianOnC}, \text{PayperPhysicianOnMT} \end{matrix} \right)_{it} = \mu_i + \tau_t + \beta_1 \text{NoStatePolicy}_i + \beta_2 \text{NoStatePolicy}_i \times \text{AfterPPSA}_t + \epsilon_{it} \quad (1c)$$

We used a log transformation for the payment variables to smooth the distributions and account for potential non-linear relationships. NoStatePolicy_i is a binary variable that indicates whether state i had PPSA-like state legislation *before* the PPSA. For example, MN had a prior state disclosure policy, so this binary variable was set to 0; its counterpart, WI, was set to 1. AfterPPSA_t is a binary variable indicating whether year t was later than the PPSA starting year of 2013. This binary variable was set to 1 for 2014–2017 and set to 0 for 2010–2013. We coded year 2013 as 0 and used ProPublica's payment data since the CMS Open Payments data only covered the last four months of 2013. The interaction term ($\text{NoStatePolicy}_i \times \text{AfterPPSA}_t$) captures the DID measure, and the significance of its coefficient, β_2 , could reveal the two-way interaction effect of the PPSA on the log-transformed *total payments*, *number of paid physicians*, and *payments per paid physician*. μ_i is the state fixed effects, capturing any time-invariant factors related to state i , and τ_t is the time fixed effects, capturing any time-invariant influences related to year t .

As our results involved six companies, multiple payment categories, even and uneven years' payments, and three dependent variables, we recorded the results for each company from 2012–2015. All *significant* DID interaction terms for the individual companies are reported in Table 2. In general, for the impact on each payment category, the DID statistics revealed that the PPSA indeed had statistically significant impact on companies' payment decisions. For the consulting category, only Merck and Pfizer had enough valid data to run DID analyses.

AstraZeneca had significant DID interactions in the meals and meals & travel categories. Per Table 2, in the meals category, AstraZeneca had a 21.89% ($1 - e^{-0.247}$) decrease in *total payments* and a 16.22% decrease in the *number of paid physicians* after the PPSA. No significant changes in *payments per paid physician* were identified for the meals category. Meanwhile, no significant interaction in the travel payment category was found. When payments for meals and travel were combined, we found one interesting significant term for the *number of paid physicians*, which showed a decrease of 20.48% after the PPSA.

Table 2. Summary of the DID Result of Significant NoStatePolicy*AfterPPSA Interactions

Firm	# OBS	Meals			Travel			# OBS	Meals & Travel		# OBS	Consulting	
		log(T_Pay)	log(P_Cnt)	log(Per_Pay)	log(T_Pay)	log(P_Cnt)	log(Per_Pay)		log(T_Pay)	log(P_Cnt)		log(T_Pay)	log(P_Cnt)
AstraZeneca	48	-0.247*	-0.177*					40	-0.229**		40		
		(0.14)	(0.09)						(0.10)				
		21.89%	16.22%						20.48%				
Eli Lilly	40	-0.313***	-0.211***	-0.557*	-0.524*			40	-0.349**		40		
		(0.10)	(0.07)	(0.29)	(0.28)				(0.13)				
		26.88%	19.02%	42.71%	40.79%				29.46%				
GlaxoSmithKline	40			-1.654***	-1.496**		40			40			
				(0.54)	(0.56)								
				80.87%	77.60%								
Novartis	40	-0.539**	-0.454*				24	-0.926**		-0.961*	24		
		(0.23)	(0.24)						(0.46)			(0.35)	
		41.67%	36.49%					60.39%	61.75%				
Pfizer	40			-0.354*			48			40	-0.858**		-0.388*
				(0.19)							(0.38)	(0.21)	
				29.81%							57.60%	32.16%	

Notes: **T_Pay** denotes Total Payments, **P_Cnt** denotes Paid Physician Count, **Per_Pay** denotes Pay per Physician. Only significant Coefficients of NoStatePolicy*AfterPPSA are reported; All payment terms are converted to US dollar 2013; Year fixed effect and state fixed effect are included; Robust standard error recorded in (); p<0.1 *, p<0.05 **, p<0.01 ***.

Eli Lilly had the most significant DID interaction terms in this study. Other than consulting, for which Eli Lilly had insufficient data, the payment categories had significant DID interactions. For meals, Eli Lilly showed a significant decrease of 26.88% in *total payments* after the PPSA. Though the *number of paid physicians* in meals did not show a significant change, the *payment per paid physician* showed a 19.02% decrease after the PPSA. For travel, we identified two significant DID terms: a reduction in *total payments* of 42.71% and reduction in *payment per paid physician* of 40.79%. As for the combined meals & travel category, *total payments* were significantly reduced by 29.46% after the PPSA.

GSK had two significant DID interactions in the travel category. No significant term was identified for

meals or the meals & travel category. However, the magnitude of changes in GSK's travel is worth mentioning. Hefty reductions of 80.87% and 77.60% in *total payments* and *payment per paid physician*, respectively, were identified and were way beyond the reductions of the other researched companies. This result might be partially due to missing data in certain states in 2012; thus further research is needed before making a valid speculation.

Novartis had a similar pattern as AstraZeneca with significant DID interactions in the meals and meals & travel categories but a stronger magnitude of reduction. After the PPSA, in the meals category, Novartis had a 41.67% decrease in *total payments* and a 36.49% decrease in the *number of paid physicians*. No significant changes in *payments per paid physician* were identified in meals. Meanwhile, no significant interaction in the travel category was found. However, when combining the payments for meals and travel, we found two interesting significant terms in *total payments* and the *number of paid physicians*, which were significantly reduced by 60.39% and 61.75%, respectively, after the PPSA. However, these observations might be biased due to the small sample size of 24 for Novartis. Further research is needed to validate these results.

Pfizer had the most complete and credible data series in our dataset. It is one of the two companies that had comparable *before* the PPSA consulting data, allowing us to have a glimpse into the company's consulting payment strategy *after* the PPSA. No significant DID interaction was identified for the meals or meals & travel categories for Pfizer. One significant reduction of 29.81% was identified for the travel category in the *number of paid physicians*. Among all companies, the only significant change was identified for this dependent variable in the travel category. As for consulting, two significant DID interactions were found: *total payments* was reduced by 57.60%, and the *number of paid physicians* was reduced by 32.16% after the PPSA. Merck was not included in Table 2, although all models were run for this company. For the meals, travel, and meals & travel categories, no significant DID term was identified. For consulting, Merck had sufficient data to conduct the DID analysis, yet it showed no significant change in all three DID models.

5. Discussion and Future Research

This research adds to the emergent literature on the impact of mandatory information disclosure on healthcare stakeholders with a focus on how policy regulations influence a company's marketing behavior and induce favorable ethical conduct. In this paper, we have examined the PPSA's effect on pharmaceutical

companies' dynamic payment strategies for one category of health service professionals: physicians. These strategies include companies' total payments, the number of physicians being paid, and the payment per paid physician for meals, travel, and consulting. Our paper is the first systematic and comprehensive study to investigate prospective changes in firm behavior after the adoption of the PPSA, and our findings indicate that firm-side payment regimes have been influenced by disclosure laws. This study not only identifies substantial variations among the six studied companies' reactions to the regulation but also reveals a common theme and several specific strategies shared among firms.

In general, after the adoption of the PPSA, most companies made adjustments by reducing overall payments to physicians, cutting the number of paid physicians, and/or lowering the payment per paid physician. Those companies that not reduce their payments or activities largely kept them unchanged instead of increasing them. Companies with higher advertisement spending were more likely to have higher total payments, as well as more physician interactions.

Prior to the PPSA, state payment disclosure policies were found to be effective in reducing companies' total payments and interactions with physicians. Interestingly, these state disclosure policies had some positive correlations to the payment per paid physician. In other words, although the state disclosure policies discouraged companies in terms of their total payments and interactions with physicians, the payment per paid physician somewhat increased in certain studied payment categories.

The reduced total payments and the lowered number of paid physicians hinted at an effective policy impact and a reduced pharmaceutical company influence on physician groups. Therefore, the PPSA could be viewed as having a certain degree of positive impact on ethical conduct. However, the increases in payment per paid physician in some cases could indicate that, after the adoption of the PPSA, companies might have been prudent in selecting effective physician groups with a well-crafted payment scheme. For instance, they might have elevated the payment amount per paid physician to make their interactions more attractive and effective, influencing key physicians' prescribing inclinations while simultaneously lowering the total payments to signal their recognition of the policy.

In light of our research findings and the comparison of marketing payments, fines, and sales revenues, we tend to agree with Parker et al.'s [27] (p.2) summary of the results of multiple previous studies: "The concrete guidance about specific promotional strategies and tools should be extended to reflect new evidence and ideas --

for example, restricting interactions between industry and prescribers or surrogate marketers, including prohibiting industry gifts to individuals or groups as well as meals, travel costs, and political donations;... and encouraging the creation of independent detailing, education, and research. The document should have sections providing guidance about important new aspects of drug promotion – for example, banning promotion of antimicrobials; mandating transparent reporting of all industry promotional costs; and prohibiting industry funded individuals from participating in policy."

Regarding the policy impact on stakeholders, we suggest two research paths to further understand the dynamics of firm and physicians' reactions to the PPSA. One path would focus on the company-side policy impact but extend the studied time periods to include more available Open Payments data. Researchers could conduct comparative analyses of the early (i.e., 2014–2016) and the later (i.e., 2017–2019) PPSA adoption phases to reveal whether the policy impacts found in this study sustained over time and to reveal any new patterns in the reactions in the later phase.

The second path would involve undertaking a granular physician-level analysis to explore the impact of PPSA on physicians' behavior changes, especially their prescribing actions, as well as their frequency of interaction and willingness to interact with pharmaceutical companies. By combining payment data with individual physician's prescribing data, one could identify the dynamics of physicians' reactions to the PPSA. Specifically, one could investigate how physicians' prescribing behaviors changed before and after the adoption of the PPSA and whether the behavior changes correlated with payments received, types of payments, number of interactions with companies, etc. One could also explore whether those influences varied across physician specialties and prescription drug categories. As we found in this study, several firms increased the payment per paid physician, and a physician-level analysis could explore correlations between the higher payments to physicians and the persuasive power of these payments on physicians' prescribing behavior. The Open Payments data also specifies the number of interactions that companies have with each physician, as well as the total payments made to each physician; this data could open new realms for exploration of physicians' behaviors and strategies.

In addition to the policy impacts on firm and physician behavior research, future studies could focus on policy enforcement and open data efficiency. Although according to CMS the PPSA is expected to yield more informed discussions between patients and their doctors [38] and information transparency is expected to promote more unbiased and ethical

decisions, the reality could be far from these goals. Multiple parties have utilized the CMS Open Payments data, but, in general, patients are still largely under-informed [19]. Hwong et al. [20] evaluated 21 state and industry disclosure websites and found that state websites were structured to transmit data to researchers and guide compliance officers rather than tailored for patients. According to Gorlach and Pham-Kanter [14], although the PPSA establishes high penalties for violations and is enforced by the Department of Justice, the PPSA provides no systematic way to check for non-compliance or the submission of poor or inaccurate information. As such, future research could explore ways to improve public awareness and enhance the accessibility and usability of the CMS Open Payments data, as well as ways to establish better mechanisms to discourage dishonest reporting, identify violations, enforce penalties, etc. Overall, we expect the present study to shed light on policy efficacy and information disclosure regulations among companies, improve companies' ethical conduct through policy intervention, and enhance patient welfare.

6. References

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