Medical Device Companies and Doctors: Do their Interactions Affect Medical Treatments ?

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Abstract

Medical device companies may play a role in the type of treatments provided to patients, namely by influencing physicians to use their products. Physicians interact frequently with medical device representatives, which raises concerns that these relationships might bias healthcare providers. Using data on payments from medical device companies to physicians combined with hospital discharge datasets, I assess the impact of payments on medical treatments. The specific setting of this study is treatment provided to heart attack patients arriving at the Emergency Room (ER) in Florida hospitals. Using an instrumental variables approach, I find that patients treated by doctors who interact with the industry are more likely to receive an invasive procedure. I find no significant impact on healthcare outcomes. However, interactions result in higher medical device costs (up to 16% increase) and total hospital costs (up to 3% increase). The results can have implications for the design of regulations on physician-industry interactions.

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1 Introduction

Interactions between pharmaceutical and medical device companies with physicians are a controversial issue in healthcare. Physicians interact frequently with the pharmaceutical and the medical device industries, and there is a large and growing public and academic debate about these interactions (e.g., Blumenthal 2004). Some argue that these interactions can be beneficial as they provide information to physicians about new drugs and devices introduced in the market, which can improve patient outcomes and advance science and technology.[1] Others however claim that they can potentially create conflicts of interest, bias healthcare providers, contribute to a loss of trust in the healthcare sector, adversely affect patient outcomes or increase healthcare resources in a wasteful way (Robertson et al. 2012).

With the aim of increasing transparency between healthcare providers and the pharmaceutical and medical device industries, the Physician Payments Sunshine Act (part of the Affordable Care Act) was adopted. Starting from September 2014, payments made from pharmaceutical companies and medical device companies to physicians are now disclosed in the US with the aim of increasing public transparency, helping patients make more informed decisions and deterring financial relationships that might increase healthcare costs (Chen et al. 2019). According to the new healthcare law, any payment or transfer value higher than \$10 individually or higher than \$100 per year must be annually reported.[2]

This paper uses data on payments from medical device companies to physicians combined with hospital discharge data to assess the impact of physician-industry interactions on medical treatments. The specific setting of this study is treatment provided to heart attack patients arriving at the Emergency Room (ER) in Florida hospitals from 2013 until 2015. To my knowledge, this is the first paper to combine data on payments from medical device companies to physicians and hospital discharge datasets, and to examine payments in the context of healthcare treatments. More than 100,000 patients were treated by 4,215 physicians in this time period in Florida. Approximately 25% of physicians treating these patients received payments from the medical device industry related to cardiac devices.

[1] For the role of physicians in the medical device innovation process, see Grennan et al. (2018).

[2] CMS (2013), p. 9485. For possible unintended consequences of payments' disclosure, namely due to a moral licensing effect that exaggerates physician's biased advice, see Loewenstein et al. (2012).

When a heart attack patient arrives at the ER, a quick decision must be made about the type of treatment. Options include an "agressive" approach (*i.e.*, invasive procedure) or a "conservative" approach (drugs). I ask whether interactions from the medical device industry might influence the type of treatment being provided.

Examining how payments from medical device companies impact medical treatments is difficult due to potential endogeneity of payments. Physicians receiving payments might have certain characteristics that are also correlated with the treatment they provide. Hence, it is possible that some unobservable characteristics might be both correlated with payments and health treatments. This issue is addressed with an identification strategy that explores an instrumental variable approach to payments. In order to do so, I consider how payments received by the physician's colleagues influence his or her own payment. I find a positive relationship between the amount of payments and the likelihood of performing an invasive procedure.

Next, I consider the impact of industry-physician interactions on patients' healthcare outcomes. The results show no significant effects on the likelihood of dying in hospital, length of hospital stay or the likelihood of being discharged home. Finally, I assess the impact on different cost variables, such as cardiology costs, medical device costs, operating room costs and total hospital costs. The IV estimates show higher medical device costs and total costs for patients treated by physicians who interact with the industry.

So far, different lines of research have tried to assess whether and how physician behaviour can be affected by different types of incentives. In recent years, a number of empirical studies have analyzed whether interactions from the pharmaceutical industry affect prescriptions made by physicians who receive payments from that same company. Most of these studies find a positive correlation between payments and prescriptions. Fernandez and Zejcirovicy (2019) find that pharmaceutical promotion is positively related to opioid prescription rates which in turn lead to an increase in opioid overdose rates. Carey et al. (2020) find that patients whose prescribers receive payments from a pharmaceutical company increase expenditure on that firm's drugs. Additionally, they also find that physicians who receive payments tend to prescribe lower quality drugs after the payment, but that the effect is very small. Grennan et al. (2018) show that meals, the most common physician-industry interaction, increase prescriptions of statin drugs. Engelberg et al. (2014) find that payments increase prescriptions of branded drugs, and that the effect is higher for doctors residing in states known to be "corrupt". Larkin et al. (2017) consider changes in US academic medical centers' policies which restrict detailing between 2006 and 2012. These policies are associated with a reduction in prescriptions of detailed drugs.

Another line of research considers the impact of financial incentives on treatments provided by physicians and there is compelling evidence that physicians react to financial incentives: physicians tend to increase the rate of procedures when treatment is profitable and reduce it when is costly (McGuire 2000). Papanicolas and McGuire (2015) find that financial incentives are relevant for a faster uptake of a new type of hip replacements (uncemented). Other papers focus on childbirth, and evidence suggests that financial incentives might influence the decision of performing a cesarean section vs a natural delivery (Currie and Gruber 2001, Gruber et al. 1999), which might differ between commercially insured mothers and mothers insured by Medicaid (Shurtz 2014).

Currently, not much is known about possible impacts of industry-doctors interactions on medical treatments, in particular those related to medical device companies. This paper aims to fill this gap. This paper proceeds as follows. Section 2 provides some background description of heart attacks and the medical device industry. Section 3 describes the data. Section 4 lays out the empirical strategy and results. Section 6 concludes.

2 Background

2.1 Heart attacks

Every year, more than 700,000 Americans have a myocardial infarction (Centers for Disease and Control Prevention). Heart attacks comprise a relevant portion of patients receiving emergency healthcare in hospitals, and are a meaningful class of patients in terms of total number of patients and costs. AMI was the top 5 most expensive condition to treat in US hospitals in 2011, accounting for 3% of national costs (Torio and Andrews 2013). Heart diseases are a major cause of death in the US.

An acute myocardial infarction (AMI), commonly referred to as a heart attack, typically occurs when a blood clot blocks the blood inflow to the heart. This medical emergency requires treatment to restore blood flow. The longer the time without treatment, the greater the damage to the heart muscle can occur. When a heart attack patient arrives at the emergency room, a quick decision about the treatment must be made. The decision entails treatment with drugs (considered as "conservative") or a more invasive approach ("aggressive"). Under the "conservative" approach, the patient is treated with clot-busting drugs. These drugs, also known as thrombolytic agents, dissolve clots in blood vessels. Under the invasive approach, the patient can receive a cardiac catheterization or angioplasty.[3]

There are different reasons to focus on heart attack cases. Focusing on cases arriving at the Emergency Room reduces concerns about physician selection. Moreover, given the emergency nature, it is also unlikely that patients can make a choice of treatment. Heart attack patients almost always search for hospital care, which implies that these patients will show up in the hospital inpatient discharge dataset. Finally, and as described above, these are relevant cases not only in terms of its numerosity but also in terms of health care costs.

2.2 Medical device industry

Medical devices have a crucial role in healthcare and can bring significant improvements in the diagnosis and treatment of diseases. In the US, the Food and Drugs Administration (FDA) regulates medical products such as medical devices, pharmaceutical drugs, vaccines, biopharmaceuticals, cosmetics and animal products. According to the FDA, medical devices can be defined as *"an instrument, apparatus, implement, machine, contrivance, implant, in vitro reagent, or other similar or related article (...) intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment, or prevention of disease (...) which is not dependent upon being metabolized for the achievement of its primary intended purposes"*.[4] The range of medical devices is immense and examples include surgical gloves, powered wheelchairs, heart valves and silicone breast implants. The regulatory framework applied to medical devices is generally less stringent than the one applied to prescription drugs, given the tendency to make incremental changes to previous products (MedPAC 2017). Nevertheless, there is also more product heterogeneity and *ex ante* uncertainty about the regulatory process

[3] Invasive procedures are defined by the following ICD-9 codes: 00.66, 36.0, 37.22, and 37.23 (Currie et al. 2016).

[4] `https://www.fda.gov/medical-devices/classify-your-medical-device/product-medical-device`, last access on March 26, 2020.

when compared to drugs (Stern 2017).

In comparison with other industries such as pharmaceuticals, we still know little about medical devices[5], with a few exceptions (*e.g.*, Stern 2017, Mojir and Sudhir 2017, Grennan 2013). The medical device sector is a relevant industry: estimates point to a total of $172 billion spending in medical devices in 2013, which corresponds to 6% of total national health expenditures (Donahoe and King 2015). According to a MedPAC report to the Congress, a few characteristics are relevant to characterize the medical device market: in the case of conventional devices (e.g., surgical gloves, included in the category Class I as it entails a low level of risk to patients) there is typically a high competition among firms, which compete on prices to achieve high sales and be profitable; in the case of advanced products (e.g., heart valves, included in the category Class III as it entails a high level of risk to patients) there is less competition among firms, it is more difficult to enter the market, but operating firms tend to obtain substantial profits. Another relevant characteristic is that there is a difference between types of companies in the market: there are a few large and diversified companies, and many small firms.

Interactions between medical device industry and physicians are common. Physicians can influence the decision of acquiring and using a medical device in a hospital context and therefore there is a strong incentive for the medical device industry to have close tights with physicians and encourage the use of their products (MedPAC 2017). Medical device companies invest significantly in these interactions. In 2015, general payments made by the pharmaceutical and medical device industry to physicians totaled almost $2.1 billion, of which 59% was made by the medical device industry (Open Payments, 2015). These interactions might result in biased decisions from physicians when deciding which treatment should be provided to their patients. Moreover, physicians do not pay the financial cost of using medical devices.

There are different cardiovascular devices approved by the FDA (Stern 2017). Considering the setting of this paper, I am particularly interested in devices which can be used to treat heart attack patients. These are essentially coronary stents, heart valves and balloon catheters.

[5]This is particularly the case for the economics literature.

3 Data and Descriptive Evidence

The empirical analysis seeks to assess whether interacting with the medical device industry can affect treatment provided to heart attack patients, their health care outcomes and costs. For this purpose, I combine several sources of data which are described in this section. First, I use the universe of hospital discharge data from Florida to identify heart attack patients. I then consider data on payments related to cardiac medical devices received by physicians treating heart attack patients in Florida.

Hospital data - I use the Florida Hospital Inpatient Discharge Data to identify heart attack patients in Florida from 2013[6] until 2015. The analysis is restricted to patients who were admitted through the ER in order to avoid possible physician selection. Additionally, and because the aim is to investigate physician behavior, I restrict the analysis to physicians who have seen at least 5 patients during this three-year period; and to hospitals where at least 15 patients were treated and where an invasive procedure could be performed.[7]

The hospital discharge data includes relevant information about patient's characteristics such as age, ethnicity, gender, type of insurance, length of stay, discharge status, and diagnostic and procedure codes. Diagnostic and procedure codes are relevant because they allow to construct several variables such as whether the patient received an invasive procedure, whether the patient was discharged home, and whether the patient died in hospital. Moreover, it also allows to construct different variables to flag comorbidities as included in the Charlson index such as: congestive heart failure, dementia, peripheral vascular disease, diabetes, coronary obstructive pulmonary disease, ulcers, kidney disease, liver disease, cancer, and HIV. It is important to include these variables because patients with a combination of serious health conditions tend to be less likely to receive invasive procedures than healthier patients.

Table 1 provides some descriptive statistics from the inpatient dataset. From a total of 117,485 patients arriving at the ER during the period of analysis, 62% received an invasive procedure, 66% were discharged home (vs being transferred to, *e.g.*, a nursing facility) and approximately 7% died in hospital. On average, these patients are 69 years old. This table also allows to check for patient's characteristics in terms of risk

[6] This is when the Open Payments dataset became available.

[7] This is consistent with previous literature. See, for instance, Currie et al. (2016). Other options can also be considered as robustness checks, and the results hold.

factors.

Table 1: Patient characteristics and outcomes

Variable	Mean	SD
Invasive	62.17	48.5
Discharged home	66.12	47.33
Died in hospital	7.36	26.11
Length of stay-days	5.83	7.7
Patient age	69.55	14.14
CHARLSON INDEX	2.7	2.11
Male patient	0.6	0.49
White patient	0.82	0.39
Black patient	0.11	0.32
Congestive Heart	0.32	0.47
Peripheral Vascular disease	0.09	0.29
Cerebrovascular disease	0.07	0.26
Dementia	0	0.07
Chronic Obstructive Pulmonary	0.23	0.42
Rheumatoid Disease	0.02	0.15
Peptic Ulcer	0.01	0.11
Mild LD (Liver)	0.01	0.1
Diabetes	0.29	0.45
HP/PAPL (Hemiplegia or Paraplegia)	0.01	0.1
Renal	0.23	0.42
Cancer	0.04	0.19
Moderate/Severe LD (Liver)	0.01	0.08
Metastatic Cancer	0.01	0.12
AIDS	0	0.05
Medicare	0.66	0.47
Medicaid	0.06	0.25
N	117485	

Each patient is assigned to a physician. In order to obtain more information about physicians who treat heart attack patients, I use the physicians medical license numbers to merge with the Florida medical license database.[8] Table 2 shows some summary statistics for physicians.

Table 2: Physician characteristics

Variable	Mean	SD
Top 20 Medical School	0.03	0.18
Spanish	0.21	0.40
Years since graduation	20.39	10.86
Male doc	0.77	0.42
N	4215	

[8] https://appsmqa.doh.state.fl.us/MQASearchServices/Home.

Physicians' practice style might be influenced by the hospital environment where the physician practices. Figure 1 shows that, within the same hospital, there is significant variation in terms of physicians use of invasive procedures. Therefore, physicians do not behave similarly within hospitals.

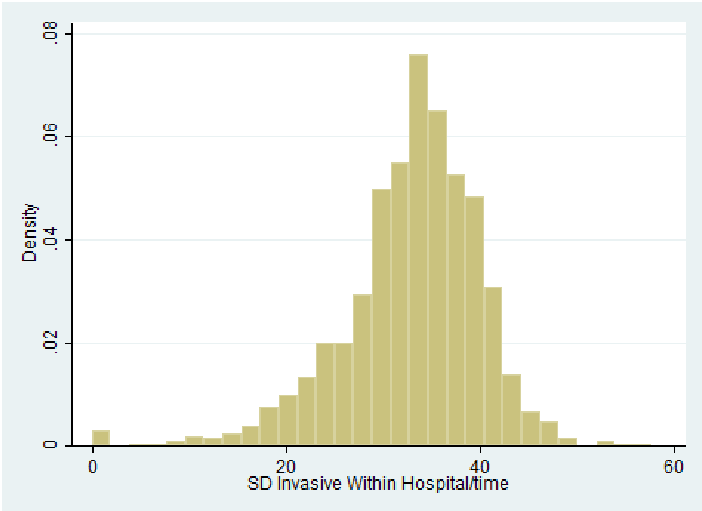

Figure 1: Standard deviation of invasive rates within hospital. It is calculated considering invasive rates of physicians working in the same hospital.

Costs data - The inpatient hospital discharge date provides information on different hospital charges but these need to be converted into costs. In order to do so, I multiply the hospital charge by the hospital's cost-to-charge ratio (CCR) provided by the Healthcare Cost and Utilization Project and standardize costs to real 2009 dollars. Due to some missing values for individual hospital CCRs, the group cost-to-charge ratio is used, which assigns the same ratio to similar hospitals in the same geographic area. Table 3 presents summary statistics for costs.

Table 3: Costs

Variable	Mean	SD
Cardio Costs	5771	5685
Medical Dev Costs	2460	4093
Operating Room Costs	1494	4653
Total Gross Costs	23,427	23,593
N	117485	

Payments - The data on payments is from the Open Payments dataset from the Centers for Medicaid and Medicare (CMS), which compiles information on payments from pharmaceutical and medical device companies to physicians. Payments can take different forms such as meals, travel, speaking fees, honoraria, gifts, or research. Many of these payments involve in-kind instead of cash payments, and the data stores the corresponding dollar value of, for instance, the meal or gift.

The dataset provides information on interactions between the industry and physicians, but not all payments are related to devices and, among payments related to devices, not all are related to cardiac devices. This paper considers only payments related to medical devices and, more specifically, those related to cardiac invasive treatments in a heart attack setting.[9]

Physician's identification in this dataset does not include the National Provider Identifier (NPI), which is unique. For this reason, I use relevant information on physicians' characteristics such as the physician's name and geographic location to obtain the National Provider Identifier (NPI) from the Physician Compare dataset. A matching based on name, surname and location provides a high number of matching cases. However, I developed a matching procedure which allows to recover a higher number of cases. For instance, in some cases, name and surname might be wrongly switched, and it is important to account for this. After recovering the NPI, I merged the payments' dataset with the hospitals' discharge data.

Approximately 24% of the physicians treating patients suffering a heart attack receive payments from the medical device industry related to cardiac devices. The average payment per quarter associated with cardiac devices is \$99.

4 Empirical Approach

The primary interest of this paper is to assess whether payments related to medical devices might influence the likelihood of performing an invasive treatment to heart attack patients. Examining this relationship is difficult due to potential endogeneity of payments. I address this issue by performing an instrumental variables approach.

In a situation in which there would be random assignment of payments and hospital practice behavior, a simple empirical model could be estimated:

$$Y_{ijht} = \alpha_1 + \alpha_2 AvDocPay_{j,t-1} + \alpha_3 P_{jt} + \alpha_4 X_{it} + \alpha_5 Hospital_h \text{x} Time_t + \epsilon_{ijht}$$

[9]These are mainly payments related to stents, heart valves, stent grafts, balloon catheter, drug coated balloons.

where the dependent variable Y is the outcome of interest and it is measured on patient i, treated by physician j, in hospital h at time t. Different outcomes are considered and can be broadly divided into three categories: i) treatment provided, ii) healthcare outcomes and iii) healthcare costs. Treatment provided considers the probability of receiving an invasive treatment (*Invasive*). Healthcare outcomes considers the probability of dying in the hospital (*Died*), the probability of being discharged home (*Discharged Home*) and hospital's length of stay (*Length of stay*). Finally, healthcare costs include cardiology costs, medical devices costs, operating room costs, and total hospital costs.

The main variable of interest is *AvDocPay*, and it is the physician's average payment per quarter related to cardiac devices. The control variables include P, which are physician's characteristics, such as being graduated from a top 20 medical school, years since graduation, physician gender and whether the physician is Spanish-speaking (see Table 2). X are patients' characteristics such as age, risk factors (as described in Table 1) and type of insurance. $Hospital\text{x}Time$ are hospital-quarter fixed-effects which enable to flexibly control for unobserved factors influencing doctor's behavior at the level of the hospital and over time. It is important to control for hospital fixed effects considering that hospitals might be able to obtain different deals with medical device suppliers.[10] Moreover, it also captures unobserved time-invariant factors related to hospital practice, as there is evidence that physician practice style might be influenced by peers (e.g., Molitor 2018). The fact that I am including hospital-time fixed effects implies that I am controlling for common practices within hospital, but also changes within hospital over time. Additionally, there is a lot of variation within hospitals in terms of individual's physicians use of invasive procedure as shown in Figure 1. This variation will be further explored for identification.

There are key challenges to estimate the equation above because the main explanatory variable, *AvDocPay*, may still be correlated with unobserved physician variables that could affect the likelihood of performing an invasive treatment. I address this concern by using an instrumental variable approach. The first-stage regression is the following:

[10]Unfortunately, there is no information on hospital purchases. A discussion on the mechanisms will follow, taking this into account.

$$AvDocPay_{jt} = \beta_0 + \beta_1 AvHospPay_{-jt} + \beta_2 AvHospPay^2_{-jt} + \beta_3 P_{jt} + \beta_4 X_{it} + \beta_5 Hospital_h \times Time_t + u_{ijt}$$

Therefore, I model the average physician payment depending on the leave-out average payment in the previous period at the hospital where the physician practices, excluding the physician's own payments. The square of the leave-out average payment is also included as the first-stage of the IV estimation suggests a non-linear effect of payments of other doctors on own payments. P includes physician's characteristics and X includes patients' characteristics. This equation should also shed light on the medical device companies' strategy in terms of how they target physicians. For instance, it is plausible to consider that the industry is more likely to target "thought leaders" (Elliott, 2006).

Medical Treatments

Columns (1) and (3) of Table 4 show the regressions results when the dependent variable is invasive, and the standard errors are clustered at the hospital-time level. As a robustness check, Tables 7 and Tables 8 in the Appendix report estimates with standard errors clustered at the physician-level and at the hospital-level, respectively. Column (1) shows the OLS results and column (3) show the IV results.[11] The estimates of the OLS and IV models indicate that receiving cardiac device payments and performing an invasive treatment are positively correlated. Considering an average invasive rate of 62%, the OLS estimates indicate that a mean-paid physician is 4% more likely to perform an invasive treatment in comparison with a never-paid physician. This estimate is likely to be biased and, to address this concern, I estimate an IV-model. The first-stage regression results are reported in column (2) of Table 4. The Kleibergen-Paap (KP) F-statistics is reported to verify the predictive power of the instrument (whic is a version of the Cragg-Donald statistic adjusted for clustered robust standard errors). These are all well above the critical value of 19.9 based on a 10% maximal IV size. Therefore, the hypothesis that the instruments are weak can be rejected. The results show a strong negative relationship between physician's mean cardiac payment and the hospital leave-out average cardiac payment. This is consistent with a horse race competition among medical device companies that have a limited budget to spend

[11] The subsequent regression results of this table do not show the first-stage results for the other outcomes because they are similar to the ones for *invasive*.

on physicians. Medical device representatives are required to have a strong expertise on the medical devices that they advertise and, when they interact with a physician, there will be fewer time and budget left to spend on another physician.

As in the OLS model, the IV estimate for average payment on invasive is positive and statistically significant. According to the IV results, a physician who receives a mean payment of $99 is approximately 3% more likely to perform an invasive treatment to a heart attack patient than a never-paid physician. The comparison between the OLS and the second-stage IV results reported in columns (1) and (3), respectively, shows that the magnitude of *AvDocPay* is lower in the IV estimate.

Table 4: Regressions: Medical procedures and healthcare outcomes

Dep. var:	Invasive	AvDocPay	Invasive	Died		Discharged Home		Length of Stay	
	OLS	IV 1st	IV 2nd	OLS	IV 2nd	OLS	IV 2nd	OLS	IV 2nd
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
AvDocPay	0.023***		0.017***	-0.000	0.001	0.006***	0.003	0.000	0.000
	(0.005)		(0.005)	(0.001)	(0.002)	(0.002)	(0.005)	(0.000)	(0.000)
AvHospPay		-0.223***							
		(0.022)							
AvHospPaySq		0.000***							
		(0.000)							
Patient characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physician characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HospitalxTime FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test			54.163		54.163		51.121		54.163
R^2	0.253		0.201	0.037	0.022	0.186	0.138	0.181	0.138
Observations	117485	117481	117481	117485	117481	108858	108852	117485	117481

Notes: The dependent variable *invasive* is 100 if an invasive procedure was performed and zero otherwise; similar to the dependent variables *died* and *discharged home*. *Length of stay* is the log of days spent at the hospital. The variable *AvDocPay* is the average dollar payment related to cardiac devices that the physician received in the previous quarter. Standard errors are clustered at the hospital-time level.

Healthcare outcomes

According to the regression results described above, interactions with the medical device industry have a positive relationship with the probability of performing certain medical treatments, even after controlling for several observable characteristics of patients and physicians. One concern is that physician-industry interactions might bias healthcare decisions and harm patients. I test for this hypothesis by considering several healthcare outcomes as shown in Table 4. These outcomes include the likelihood of dying in hospital (columns (4) and (5)), being discharged home (columns (6) and (7)) and length of hospital stay (columns (8) and (9)). According to the IV results, payments related to cardiac devices have no statistically significant impact on patients' healthcare outcomes. Therefore, there is no evidence that medical device industry - physician interactions harm patients. However, and according to these results, there is also no evidence that it improves healthcare either. Unfortunately, I cannot observe whether patients are readmitted to hospital at a later point in time. This could be an additional way of testing the impact on healthcare outcomes.

Costs

Table 5 presents the regression results for different types of medical costs: cardiology costs (columns (1) and (2)), medical devices costs (columns (3) and (4)), operating room costs (columns (5) and (6)) and total hospital costs (columns (7) and (8)). An interesting result emerges from this table: payments related to cardiac devices have no impact on cardiology costs or operating room costs, which are the two costs categories which are not directly related to those payments. However, payments have a statistically significant impact on medical device costs and total healthcare costs. Back of the envelope calculations point to an increase of up to 16% in medical device costs and up to 3% in total hospital costs.

Table 5: Regressions: Types of Costs (Clustered SE at the hospital-time level)

Dep. var:	Cardiology		Med Device		Operating Room		Total	
	OLS	IV 2nd	OLS	IV 2nd	OLS	IV 2nd	OLS	IV 2nd
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
AvDocPay	0.531**	0.222	2.806***	4.039***	2.568***	0.682	9.956***	6.252**
	(0.243)	(0.597)	(0.682)	(1.322)	(0.647)	(0.824)	(2.311)	(2.654)
Patient characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physician characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HospitalxTime FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.562	0.495	0.192	0.087	0.087	0.026	0.159	0.073
Observations	117343	117339	117343	117339	117343	117339	117343	117339

Notes: The variable *AvDocPay* is the average dollar payment related to cardiac devices that the physician received in the previous quarter. Standard errors are clustered at the hospital-time level.

4.1 Patients' appropriateness

I now consider whether payments can affect differently the use of invasive procedure depending on patients' underlying risk factors/appropriateness to receive an invasive procedure. Patients with a combination of serious health conditions tend to be less appropriate to receive invasive procedures than healthier patients. Patients suffering from commorbidities included in the Charlson index such as congestive heart failure, dementia, peripheral vascular disease, diabetes, coronary obstructive pulmonary disease, ulcers, kidney disease, liver disease, cancer, and HIV are in principle poorer candidates for invasive procedures, in comparison with patients with no such conditions. Moreover, older patients tend to be poorer candidates as well. Therefore, I use patients' characteristics to identify good and poor candidates for invasive procedures, similar in spirit with previous literature (see Currie et al. (2016)). In order to do so, I estimate a logit model in which the dependent variable is *invasive* and the covariates are the observable patient characteristics. Quarter fixed effects are also included. From here, and based on percentiles, patients are divided into 3 groups: low appropriateness (below the 33th percentile), middle appropriateness (from the 34th until the 66th percentile) and high appropriateness (above the 66th percentile).

The results on Table 6 show a higher impact for patients who are poorer candidates for an invasive procedure. Subsequently, patients in the middle range follow. Finally, the results show that the effect for patients in the high appropriateness group are also statistically significant. However, the magnitude of the coefficient is rather small. These results show evidence that, in case patients' appropriateness for invasive procedure is high, both physicians who interact and those who interact with the industry tend to provide treatments in a similar way. The differences are larger for patients with the lowest level of appropriateness. Physicians who do not interact with the industry are less likely to perform an invasive procedure on patients of this type.

Table 6: Regressions: Invasive according to appropriateness (Clustered SE at the hospital-time level)

Dep. var:	Invasive		
	Low Appropriateness	Middle Appropriateness	High Appropriateness
	(1)	(2)	(3)
AvDocPay	0.056***	0.026**	0.009**
	(0.016)	(0.011)	(0.004)
Patient characteristics	Yes	Yes	Yes
Doctor characteristics	Yes	Yes	Yes
Hospital x Time FE	Yes	Yes	Yes
F-test	22.908	28.723	43.235
R^2	0.075	0.024	0.028
Observations	37468	39946	40009

Notes: The variable *AvDocPay* is the average dollar payment related to cardiac devices that the physician received in the previous quarter. Standard errors are clustered at the hospital-time level.

5 Discussion

The results in this paper provide evidence that interactions between the medical device industry and physicians play a role on how to treat heart attack patients. I discuss some relevant ways in which these interactions could influence treatment decisions.

Medical devices evolve rapidly and a significant proportion of doctors was not exposed to current technologies during their medical training. Therefore, physicians might need medical device representatives to explain how to use certain devices (Kruger and Kruger 2012). Moreover, many products are updated or improved on a regular basis and physicians need to keep up with technology. The interactions with the industry might be an informative channel to physicians, so that they can be more knowledgeable of the available options.

Medical device companies might try to influence hospitals' purchase decisions via their interactions with physicians. Typically, medical device representatives' salary depend at least partially on sales, and it seems natural to expect that they will try to influence the use of their devices. Still, evidence points to the fact that the number of interventional cardiologists that make brand selection is extremely low (Kruger and Kruger 2012). These interactions might allow medical device representatives to establish a trust relationship with physicians, so that they can try to influence them in the future when new devices are introduced in the market.

Physicians' incentives should also be considered. The average payment is $99, which represents a low amount in comparison with physicians' salary. It seems more plausible that physicians are influenced due to the information that they receive instead of the financial incentive *per se*. In order to be able to draw further conclusions on this point, additional data on hospitals' purchases would be needed.

Finally, malpractice pressure also plays a role in preventing physicians from providing harmful treatments to patients. Evidence shows that malpractice pressure influences physician behavior, and it balances possible negative effects arising from interactions with the industry.

6 Conclusion

This paper conducts the first empirical study of the impact of interactions between medical device companies and physicians on treatments. The empirical context is heart attack patients arriving at the emergency room in Florida hospitals. By combining different datasets and performing different empirical analysis, I find that patients treated by physicians who interact with the medical device industry are more likely to receive an invasive treatment.

While this paper finds no significant impact on healthcare outcomes of patients treated by physicians who interact with the cardiac device industry, the findings do not allow to conclude whether these interactions are desirable. I find that medical device costs and total hospital costs tend to be higher for treatments provided by physicians who interact with the industry.

Finally, while there are no clear medical guidelines for heart attack patients, prior research has largely found that malpractice pressure plays a role in physicians' behavior (e.g., Shurtz (2014), Currie and MacLeod (2008)). Therefore, physicians might interact with the industry without putting patients at risk - even though this might result in higher healthcare costs.

This paper contributes to the understanding of physicians-industry interactions and their impact on treatments. More work is needed in order to better understand the implications of these interactions in other types or treatments, in hospitals' purchase decisions and in industry profits. Results from this research can be helpful to design legislation on physicians-industry interactions.

Appendix

Table 7: Regressions: Medical procedures and healthcare outcomes
(Standard errors clustered at the physician level)

Dep. var:	Invasive	AvDocPay	Invasive	Died		Discharged Home		Length of Stay	
	OLS	IV 1st	IV 2nd	OLS	IV 2nd	OLS	IV 2nd	OLS	IV 2nd
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
AvDocPay	0.023***		0.017***	-0.000	0.001	0.006***	0.003	0.000	0.000
	(0.005)		(0.006)	(0.001)	(0.003)	(0.002)	(0.005)	(0.000)	(0.000)
AvHospPay		-0.223***							
		(0.025)							
AvHospPaySq		0.000***							
		(0.000)							
Patient characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physician characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HospitalxTime FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test			40.929		40.929		38.618		40.929
R^2	0.253		0.201	0.037	0.022	0.186	0.138	0.181	0.138
Observations	117485	117481	117481	117485	117481	108858	108852	117485	117481

Notes: The dependent variable *invasive* is 100 if an invasive procedure was performed and zero otherwise; similar to the dependent variables *died* and *discharged home*. *Length of stay* is the log of days spent at the hospital. The variable *AvDocPay* is the average dollar payment related to cardiac devices that the physician received in the previous quarter. Standard errors are clustered at the physician level.

Table 8: Regressions: Medical procedures and healthcare outcomes
(Standard errors clustered at the hospital level)

Dep. var:	Invasive	AvDocPay	Invasive	Died		Discharged Home		Length of Stay	
	OLS	IV 1st	IV 2nd	OLS	IV 2nd	OLS	IV 2nd	OLS	IV 2nd
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
AvDocPay	0.023***		0.017***	-0.000	0.001	0.006***	0.003	0.000	0.000
	(0.006)		(0.005)	(0.002)	(0.002)	(0.002)	(0.006)	(0.000)	(0.000)
AvHospPay		-0.223***							
		(0.028)							
AvHospPaySq		0.000***							
		(0.000)							
Patient characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physician characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HospitalxTime FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test			49.077		49.077		46.838		49.077
R^2	0.253		0.201	0.037	0.022	0.186	0.138	0.181	0.138
Observations	117485	117481	117481	117485	117481	108858	108852	117485	117481

Notes: The dependent variable *invasive* is 100 if an invasive procedure was performed and zero otherwise; similar to the dependent variables *died* and *discharged home*. *Length of stay* is the log of days spent at the hospital. The variable *AvDocPay* is the average dollar payment related to cardiac devices that the physician received in the previous quarter. Standard errors are clustered at the hospital level.

Table 9: Regressions: Types of Costs (Clustered SE at the physician level)

Dep. var:	Cardiology		Med Device		Operating Room		Total	
	OLS	IV 2nd	OLS	IV 2nd	OLS	IV 2nd	OLS	IV 2nd
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
AvDocPay	0.531**	0.222	2.806***	4.039***	2.568***	0.682	9.956***	6.252**
	(0.270)	(0.784)	(0.692)	(1.287)	(0.770)	(1.202)	(2.760)	(3.064)
Patient characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physician characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HospitalxTime FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.562	0.495	0.192	0.087	0.087	0.026	0.159	0.073
Observations	117343	117339	117343	117339	117343	117339	117343	117339

Notes: Each type of cost is in log. The variable *AvDocPay* is the average dollar payment related to cardiac devices that the physician received in the previous quarter. Standard errors are clustered at the physician level.

Table 10: Regressions: Types of Costs (Clustered SE at the hospital level)

Dep. var:	Cardiology		Med Device		Operating Room		Total	
	OLS	IV 2nd	OLS	IV 2nd	OLS	IV 2nd	OLS	IV 2nd
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
AvDocPay	0.531*	0.222	2.806***	4.039***	2.568**	0.682	9.956***	6.252**
	(0.307)	(0.706)	(0.855)	(1.368)	(1.054)	(1.207)	(3.355)	(3.141)
Patient characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physician characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HospitalxTime FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.562	0.495	0.192	0.087	0.087	0.026	0.159	0.073
Observations	117343	117339	117343	117339	117343	117339	117343	117339

Notes: Each type of cost is in log. The variable *AvDocPay* is the average dollar payment related to cardiac devices that the physician received in the previous quarter. Standard errors are clustered at the hospital level.

7 Heterogeneities

Table 11: Regressions: Hospital type (Clustered SE at the hospital-time level)

	OLS	IV 1st	IV 2nd	OLS	IV 1st	IV 2nd
	Investment Owned			Not-For-Profit Urban		
Dep. var:	Invasive	AvDocPayCarDev	Invasive	Invasive	AvDocPayCarDev	Invasive
	(1)	(2)	(3)	(4)	(5)	(6)
AvDocPay	0.022***		0.027**	0.022***		0.014***
	(0.007)		(0.012)	(0.006)		(0.005)
AvHospPay		-0.206***			-0.233***	
		(0.035)			(0.026)	
AvHospPaySq		0.000***			0.000***	
		(0.000)			(0.000)	
Patient characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Doctor characteristics	Yes	Yes	Yes	Yes	Yes	Yes
HospitalxTime FE	Yes	Yes	Yes	Yes	Yes	Yes
F-test			20.107			39.490
R^2	0.248		0.192	0.258		0.207
Observations	47505	47505	47505	69560	69556	69556

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