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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, stents or Coronary-Artery Bypass Graft (CABG). I find no significant impact on healthcare outcomes. However, interactions result in slightly higher medical costs. 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 (CMS 2013). [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

[1] For the role of physicians in the medical device innovation process, see Mojir and Sudhir (2022).

[2] 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).

payments from medical device companies to physicians and hospital discharge data, 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.

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 to these patients. I then make a further distinction and consider, within invasive treatments, those involving CABG (Coronary-Artery Bypass Graft) or the use of stents.

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 physicians graduated from similar cohorts influence their own payment. Therefore, I use as instrument for each physician's payments a leave-out mean payment of physicians attending medical school in approximate years.

The rationale for using this instrument comes from the influence of the peer group on doctor's attitude towards receiving payments from device manufacturers. Because the influence of the peer group might apply to different dimensions of doctor's health practices (Agha and Zelter, 2022; Molitor, 2018), I include as a control variable a cohort fixed effect, which captures elements such as the type of training that the doctor received (and his/her cohort received) when attending medical school, and other cohort common characteristics. Moreover, I include hospital times time fixed effects to account for common hospital practices. I also verified that, within the same hospital, there is significant variation with respect to physicians' invasive procedure rates. This is reassuring as it confirms that doctors practicing in the same hospital have different approaches to treat patients with similar conditions. Thus the variation that I am exploiting to shift doctors' payments is only coming from payments received by the cohort peers at medical school and not by other characteristics of the group. I find a positive relationship between the amount of payments and the likelihood of performing an invasive procedure, CABG or using stents.

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, the likelihood of being discharged home, or length of hospital stay. 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 slightly higher medical 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 with pharmaceutical companies affect prescriptions made by physicians who receive payments from those same companies. Most of these studies find a positive correlation between payments and prescriptions. Fernandez and Zejcirovic (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. (2021) find that patients whose prescribers receive payments from a pharmaceutical company increase expenditure on that firm's drugs. Additionally, they show that drug quality is unaffected by payments. Moreover, they also consider case studies of major drugs going off patent to assess whether doctors receiving payments from the industry transition their patients to a generic version of the drug. The results show that paid physicians move patients to the generic version of the drug as quickly as unpaid physicians. Grennan et al. (2021) use machine learning methods and show that meals, the most common physician-industry interaction, increase prescriptions of statin drugs. Interestingly, the authors estimate heterogeneous effects of payments with pharmaceutical companies targeting highly responsive physicians and not targeting those who appear non-responsive. Additionally, their welfare analysis points to consumers being worse off with payments, which can be due to some frictions. However, when using clinical data to calibrate such frictions, consumers could actually be better off. Newham and Valente (2022) also find substantial variation in physicians' responsiveness to payments. Additionally, and using machine-learning, they show that while the value of payment is important when patients have high out-of-pocket costs, it is negligible when patients are heavily insured. 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. Agha and Zeltzer (2022) show that payments increased prescriptions for marketed anticoagulants, with peer spillovers contributing for approximately 25% of the increase. In another work with Calzolari, Denicolo and Nardotto (2022) we also find evidence that payments influence prescriptions, with the Sunshine Act having an impact on competition between pharmaceutical firms.

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, section 5 discusses the results, and section 6 concludes.

2 Background

2.1 Heart attacks

Every year, more than 800,000 people in the US have a myocardial infarction (AMI), commonly referred to as a heart attack.[3] 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 2017, accounting for 3% of national costs (Liang et al. 2020). Heart diseases are the leading cause of death in the US.

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"

[3] Centers for Disease and Control Prevention, https://www.cdc.gov/heartdisease/facts.htm, last accessed May 2022.

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.[4]

There are different reasons to focus on heart attack cases. To start with, focusing on cases arriving at the Emergency Room reduces concerns about physician selection. Moreover, given the emergency nature, it is highly unlikely that patients are able of making a choice of treatment. Additionally, 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"*.[5] 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

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

[5] `https://www.fda.gov/medical-devices/classify-your-medical-device/product-medical-device`, last access on March 20, 2022.

also more product heterogeneity and *ex ante* uncertainty about the regulatory process when compared to drugs (Stern 2017).

In the economics literature, fewer attention has been devoted to the medical device industry in comparison with, for instance, the pharmaceutical industry, with a few exceptions (*e.g.*, Stern 2017, Mojir and Sudhir 2022, Grennan 2013). The medical device sector is a relevant industry: estimates point to a total of $199 billion spending in medical devices in 2019, which corresponds to more than 5% of total national health expenditures (Donahoe 2021). 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. In some cases, physicians can influence the decision of acquiring and using a medical device in a hospital context. 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). Nevertheless, and considering the type of cases addressed in this paper, the number of interventional cardiologists able to have a role in product choice is extremely low (Kruger and Kruger 2012). Overall, medical device companies invest significantly in interactions with practitioners. 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.

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 2013until 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.[6]

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 be-

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

cause they allow to construct several variables such as whether the patient received an invasive procedure, whether a CABG was performed, whether stents were used, 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 more than 116,000 patients arriving at the ER during the period of analysis, 62% received an invasive procedure, 35% received stents, 6% received a CABG, 66% were discharged home (vs being transferred to, *e.g.*, a nursing facility) and approximately 7% died in hospital. On average, these patients were 69 years old. This table also allows to check for patient's characteristics in terms of risk factors such as age and comorbidities.

Upon arrival at the hospital, 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.[7] Using the information about the medical school attended, I use the US News and World Reports rankings to know if they attended a top 20 medical school. Table 2 shows summary statistics for physicians.

Physicians' practice style might be influenced by the hospital environment where the physician practices. It would be a concern if doctors practicing in the same hospital show very similar practice styles in the sense of opting for an invasive procedure in the vast majority of cases or by treating patients with drugs in the vast majority of cases. What Figure 1 shows is that, within the same hospital, there is significant variation

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

Table 1: **Patient characteristics and outcomes**

Variable	Mean	SD
Invasive	62.42	48.43
Stents	35.67	47.90
CABG	5.72	23.23
Discharged home	66.3	47.27
Died in hospital	7.35	26.09
Length of stay *(days)*	5.84	7.65
Patient age *(years)*	69.51	14.09
Charlson Index *(0-17)*	2.7	2.11
Male patient	59.68	49.05
White patient	81.54	38.8
Black patient	11.5	31.91
Congestive Heart	31.69	46.53
PVD (Peripheral Vascular)	9.32	29.06
CEVD (Cerebrovascular	7.33	26.06
Dementia	0.49	7.02
COPD (Chronic Obstructive Pulmonary)	22.71	41.89
Rheumatoid Disease	2.21	14.71
PUD (Peptic Ulcer)	1.28	11.24
Mild LD (Liver)	0.97	9.83
Diabetes	28.89	45.32
HP/PAPL (Hemiplegia or Paraplegia)	1.05	10.2
Renal	22.51	41.76
Cancer	3.75	18.99
Moderate/Severe LD (Liver)	0.68	8.22
Metastatic Cancer	1.35	11.53
AIDS	0.25	4.96
Medicare	66.33	47.26
Medicaid	6.45	24.57
N	116,958	

Note: Variables are 0-100, except when mentioned differently *(in italic)*.

Table 2: **Physicians' characteristics**

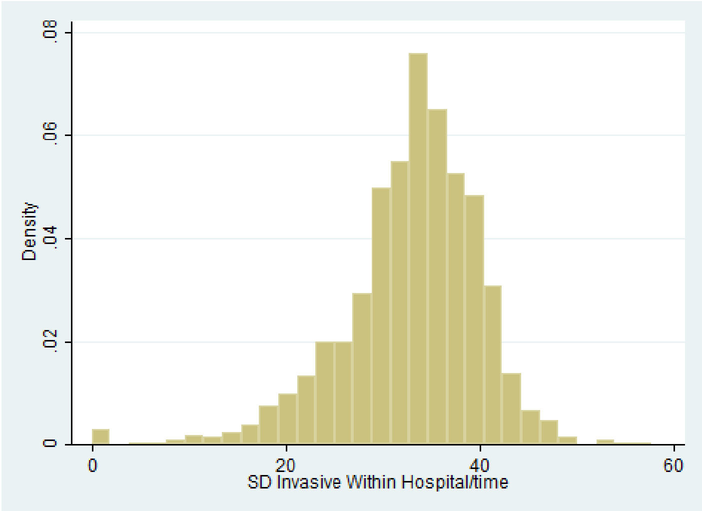
Variable	Mean	SD
Top 20 Medical School	3.39	18.09
Spanish	20.59	40.43
Years since graduation *(years)*	20.39	10.86
Male doc	76.71	42.27
N	4215	

Notes: Variables are 0-100, except when mentioned differently *(in italic)*.

in terms of physicians use of invasive procedures. Therefore, physicians do not behave similarly within hospitals, which is relevant for the empirical strategy.

Costs data - The inpatient hospital discharge data provides information on dif-

Figure 1: **Standard deviation of invasive rates within hospital.**



Notes: Considers invasive rates of physicians working in the same hospital.

ferent 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: **Medical 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	116,958	

Notes: Values in dollars.

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. Therefore, I then consider only payments related to medical devices and, more specifically, those related to cardiac invasive treatments in a heart attack setting.[8]

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 which include the physician's name, surname and geographic location to obtain the National Provider Identifier (NPI) from the Physician Compare dataset. Subsequently, I try to recover some cases by replacing the name by the surname, and the surname by the name. As it is apparent after inspecting the dataset, there are a few cases in which name and surname are incorrectly switched. After recovering the NPI, I merge 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 $98. This is higher than the average payment associated with drugs and provided by the pharmaceutical industry.

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

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

of payments stemming from correlation between payments and unobserved doctor's characteristics. One example of a mechanism that might generate such correlation is when the industry targets particular types of doctors who respond to payments more than others. Some evidence of this has been reported in the case of payments by drugs' manufacturers (e.g., Carey et al., 2021; Grennan et al., 2021), although I am not aware of similar evidence on payments provided by medical device companies. However, this is a plausible hypothesis and the lack of evidence might be due to the fact that research so far has focused more on pharmaceutical companies than on producers of medical devices. I address this issue by performing an instrumental variables approach.

To start with, the goal of this study is to estimate a relationship between a medical outcome (*e.g.*, the treatment selected by the doctor, or the health outcome of the patient) as a function of the value of payments received by the doctor, controlling for observed doctor's characteristics and other controls. In a situation where payments were given at random by device producers, we could estimate a model as in equation (1):

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

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 (by quarter). 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*), the probability of receiving a CABG (*CABG*); and the probability of receiving stents (*Stents*). 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 time period 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 and type of insurance (as described in Table 1). $Hospital$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 (Grennan and Swanson (2022)).[9] 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 is reassuring as it confirms that doctors practicing in the same hospital have different practice styles and will be further explored for identification.

As discussed in the beginning of this section, there is a key challenge to estimate equation (1) because the main explanatory variable, *AvDocPay*, after controlling for doctor's characteristics and the large set of fixed effects and trends, may still be correlated with unobserved physician characteristics that could affect both the likelihood of performing an invasive treatment and the likelihood of receiving payments. For this reason, the treatment of interest *receiving a payment* cannot be viewed as randomly assigned.

Therefore, I propose an instrumental variable strategy where I employ the average

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

payment received by doctors in Florida from the same cohort of medical school, excluding the physician's own payments, as an instrument for each physician's own payments. Hence, the instrument is the leave-out mean payment of physicians attending medical school in approximate years. The rationale for using this instrument comes from the influence of the cohort group on doctor's attitude towards receiving payments from device manufacturers. Because the influence of the peer group might apply to different dimensions of doctor's health practices (Agha and Zelter, 2022; Molitor, 2018), I include as a control variable a cohort fixed effect, which captures elements such as the type of training that the doctor received (and corresponding cohort) when attending medical school, and other cohort common characteristics. Moreover, to better control for possible common practices taught at medical school at the time of graduation, I also include the precise year of graduation fixed effects. It is also important to consider that, as shown in Figure 1, within the same hospital, there is significant variation with respect to physicians' invasive procedure rates. This is reassuring in the sense that physicians practicing together have considerable different practice styles. Thus the variation that I am exploiting to shift doctors' payments is only coming from payments received by the cohort peers at medical school and not by other characteristics of the group.

Besides the issue of correlation between doctor's characteristics and payments, which I address with the instrument just explained, it is worth noticing again that patients are being treated in the Emergency Room due to a heart attack, which eliminates concerns about potential selection of physicians. Therefore, the link between payments and doctors' choices can be causally estimated following a standard IV-2SLS procedure. The first-stage equation is as follows:

$$AvDocPay_{jt} = \beta_0 + \beta_1 AvCohortPay_{-jt} + \beta_2 P_{jt} + \beta_3 X_{it} + \beta_4 Hospital_h \times Time_t + u_{ijt}$$

where $AvCohortPay_{-jt}$ is the average payment received within a cohort, and excluding the physician's own payments. P includes physician's characteristics. X includes patients' characteristics. *Hospital* x *time* fixed-effects are also included, to account for common hospital practices but which can change over time.

The results for the first-stage (Table 4, column (1)), show that the leave-out mean payment of same cohort physicians is positively correlated with average physician's payments, the explanatory variable of interest. The Kleibergen-Paap (KP) F-statistics is reported to verify the predictive power of the instrument (which is a version of the Cragg-Donald statistic adjusted for clustered robust standard errors). These are all well above the critical value of 16.4 based on a 10% maximal IV size. Therefore, the hypothesis that the instruments are weak can be rejected.

Medical procedures

I estimate the impact of payments on the likelihood of performing different medical procedures according to the equation (1), but instrumenting for *AvDocPay* using the mean leave-out payment from similar cohorts. Column (3) of Table 4 shows the OLS regression results when the dependent variable is invasive, and the standard errors are clustered at the hospital level.[10] After the first-stage results on column (1), the IV regression results are shown on column (2).[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 3% more likely to perform an invasive treatment in comparison with a never-paid physician. As this estimate is likely to be biased, the results for the IV-model are also presented.

As in the OLS model, the IV estimates for the affect of payments on invasive treatment (column (2)), use of stents (column (5)) and CABG (column (7)) are positive and statistically significant. According to the IV results, a physician who receives a mean

[10]As a robustness check, Table 13 in the Appendix report estimates with standard errors clustered at the physician-level.

[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*.

Table 4: **Regressions: Medical procedures**

Dep. var:	AvDocPay	Invasive		Stent		CABG	
	IV 1st	IV 2nd	OLS	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Av doc pay/time		0.107***	0.021***	0.014**	0.115***	0.015***	0.069***
		(0.027)	(0.006)	(0.006)	(0.028)	(0.006)	(0.019)
Av cohort pay	0.026***						
	(0.003)						
Patient characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physician characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Graduation year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HospitalxTime FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
KP F-stat		88.593			88.593		88.593
Observations	116954	116954	116958	116958	116954	116958	116954

Notes: The dependent variable *invasive* is 100 if an invasive procedure was performed and zero otherwise; similar to the dependent variables *Stents* and *CABG*. Standard errors are clustered at the hospital level.

payment of $98 is approximately 17% more likely to perform an invasive treatment to a heart attack patient than a never-paid physician; 30% more likely to use stents; and more than doubles the odds of performing a CABG.

Healthcare outcomes

According to the regression results described above, interactions with the medical device industry have a positive relationship with the probability of performing an invasive procedure, using stents or performing CABG, even after controlling for several observable characteristics of patients and physicians. One concern is that, by interacting with the industry, physicians might be influenced in ways that bias healthcare decisions and, as a result, might harm patients. This would obviously be a worrying evidence and reason for concern.

I test for this hypothesis by considering several healthcare outcomes as shown in Table 5. These outcomes include the likelihood of dying in hospital (columns (1) and (2)), the likelihood of being discharged home (columns (3) and (4)) and length of hospital stay (columns (5) and (6)). According to the IV results, payments related to cardiac devices have no statistically significant impact on patients' healthcare outcomes, considering that none of the coefficients is statistically significant. 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. For instance, even though the coefficient for average payment when the dependent variable is died in the hospital is negative for the IV, it is not statistically significant. The coefficient for the average payment when the dependent variable is discharged home is positive, which could indicate a better outcome, but the coefficient is also not statistically significant. The coefficient when the dependent variable is length of stay is equal to zero, but it is also not statistically significant. All these healthcare outcomes can be observed from the hospital discharge dataset. Nevertheless, I cannot observe whether patients are readmitted to hospital at a later point in time, which could be an additional way of testing the impact on healthcare outcomes.

Table 5: **Regressions: Healthcare Outcomes**

Dep. var:	Died		Discharged Home		Length of Stay	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Av doc pay/time	0.000	-0.003	0.005**	0.008	0.000	0.000
	(0.001)	(0.012)	(0.002)	(0.018)	(0.000)	(0.000)
Av cohort pay						
Patient characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Physician characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Graduation year FE	Yes	Yes	Yes	Yes	Yes	Yes
HospitalxTime FE	Yes	Yes	Yes	Yes	Yes	Yes
KP F-stat		89.560		85.792		89.560
R^2	0.037	0.022	0.184	0.138	0.180	0.138
Observations	116958	116954	108382	108378	116958	116954

Notes: The dependent variables *died* and *discharged home* are 100 if the patient died in the hospital or discharged home. *Length of stay* is the log of days spent at the hospital. Standard errors are clustered at the hospital level.

Costs

I also assess whether doctors interacting with the medical device industry might provide more costly treatments to patients. This would be a reason of concern if there are no corresponding better healthcare outcomes. Table 6 presents the regression results for different types of medical costs: cardiology costs (columns (1) and (2), for OLS and IV, respectively), medical device costs (columns (3) and (4)), operating room costs (columns (5) and (6)) and total hospital costs (columns (7) and (8)). According to the IV estimates, cardiac device payments have a statistically significant positive impact on costs. Even though the magnitude of the coefficient is quite small, there are thousands of patients being treated for this condition every year. Therefore, the overall cost increase is not irrelevant. Due to a lack of data on additional healthcare outcomes (including readmissions) it is not possible to assess whether these costs increase resulted in better or worse outcomes for patients.

Table 6: **Regressions: Types of Costs**

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)
Av doc pay/time	0.000**	0.001**	0.001***	0.003***	0.001**	0.003**	0.000***	0.001***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)
Patient characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physician characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Graduation year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HospitalxTime FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.798	0.773	0.386	0.294	0.273	0.076	0.298	0.191
Observations	105568	105565	109251	109247	29957	29897	116824	116820

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.

4.1 Patients' appropriateness

I now consider whether payments can affect differently the treatments provided to patients 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. Time 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 7 show a higher impact for patients who are in the middle range of appropriateness. Subsequently, patients in the low 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 smaller.

These results show evidence that, in case patients' appropriateness for invasive procedure is high, the differences of treatments provided by physicians who interact with the industry and those who do not tend to be smaller. The biggest differences are seen for the group of patients considered to have middle appropriateness. It is interesting to note from Table 9 that physicians who interact with the industry are not more likely to perform CABG in patients with low appropriateness levels of invasive. This is reassuring as CABG is quite invasive. Therefore, doctors are not being influenced in ways that might result in providing very aggressive treatments to patients when inappropriate.

Table 7: **Regressions: Invasive according to appropriateness**

Dep. var:	Invasive		
	Low Appropriateness	Middle Appropriateness	High Appropriateness
	(1)	(2)	(3)
Av doc pay/time	0.112*	0.131***	0.081***
	(0.057)	(0.039)	(0.019)
Patient characteristics	Yes	Yes	Yes
Doctor characteristics	Yes	Yes	Yes
Graduation year FE	Yes	Yes	Yes
Hospital x Time FE	Yes	Yes	Yes
F-test	78.009	87.018	79.553
Observations	37302.000	39815.000	39779.000

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 level.

Table 8: **Regressions: Stents according to appropriateness**

Dep. var:	Stents		
	Low Appropriateness	Middle Appropriateness	High Appropriateness
	(1)	(2)	(3)
Av doc pay/time	0.059*	0.134***	0.111***
	(0.034)	(0.040)	(0.031)
Patient characteristics	Yes	Yes	Yes
Doctor characteristics	Yes	Yes	Yes
Graduation year FE	Yes	Yes	Yes
Hospital x Time FE	Yes	Yes	Yes
F-test	78.009	87.018	79.553
Observations	37302	39815	39779

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 level.

Table 9: **Regressions: CABG according to appropriateness**

Dep. var:	CABG		
	Low Appropriateness	Middle Appropriateness	High Appropriateness
	(1)	(2)	(3)
Av doc pay/time	0.040	0.101***	0.072***
	(0.026)	(0.029)	(0.016)
Patient characteristics	Yes	Yes	Yes
Doctor characteristics	Yes	Yes	Yes
Graduation year FE	Yes	Yes	Yes
Hospital x Time FE	Yes	Yes	Yes
F-test	78.009	87.018	79.553
Observations	37302	39815	39779

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 level.

4.2 Heterogeneities: Type of Hospital

I also consider potential heterogeneities in terms of treatments provided to patients depending on the type of hospitals: not-for-profit urban hospitals[12] and investment owned hospitals. As shown in Table 10, Table 11 and Table 12, physicians working in Not-for-profit urban hospitals are more likely to perform an invasive treatment, CAB or use stents in comparison with physicians working in investment owned hospitals.

Table 10: **Regressions for Invasive: Hospital type**

	OLS	IV	OLS	IV
	Investment Owned		Not-For-Profit Urban	
Dep. var:	Invasive			
	(1)	(2)	(3)	(4)
Av doc pay/time	0.011**	0.027	0.025***	0.156***
	(0.005)	(0.044)	(0.008)	(0.031)
Patient characteristics	Yes	Yes	Yes	Yes
Doctor characteristics	Yes	Yes	Yes	Yes
Graduation year FE	Yes	Yes	Yes	Yes
Hospital x Time FE	Yes	Yes	Yes	Yes
F-test		28.254		67.974
R^2	0.243	0.190	0.257	0.174
Observations	47126	48158	69413	69771

Table 11: **Regressions for Stents: Hospital type**

	OLS	IV	OLS	IV
	Investment Owned		Not-For-Profit Urban	
Dep. var:	Stents			
	(1)	(2)	(3)	(4)
Av doc pay/time	0.006	0.046	0.018**	0.161***
	(0.004)	(0.044)	(0.009)	(0.036)
Patient characteristics	Yes	Yes	Yes	Yes
Doctor characteristics	Yes	Yes	Yes	Yes
Graduation year FE	Yes	Yes	Yes	Yes
Hospital x Time FE	Yes	Yes	Yes	Yes
F-test		28.254		67.974
R^2	0.162	0.117	0.174	0.089
Observations	47126	48158	69413	69771

[12] There are almost no observations for not-for-profit rural hospitals.

Table 12: **Regressions fo CABG: Hospital type**

	OLS	IV	OLS	IV
	Investment Owned		Not-For-Profit Urban	
Dep. var:	CABG			
	(1)	(2)	(3)	(4)
Av doc pay/time	0.007	0.045*	0.019**	0.088***
	(0.005)	(0.023)	(0.008)	(0.025)
Patient characteristics	Yes	Yes	Yes	Yes
Doctor characteristics	Yes	Yes	Yes	Yes
Graduation year FE	Yes	Yes	Yes	Yes
Hospital x Time FE	Yes	Yes	Yes	Yes
F-test		28.254		67.974
R^2	0.054	0.012	0.077	-0.017
Observations	47126	48158	69413	69771

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 might 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), even though it is not the case in the precise setting analysed in this paper. 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 $98, 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. However, even though average payments provided by pharmaceutical companies are considerably lower than those provided by medical device firms, physicians are nevertheless influenced by payments when it comes to drug prescriptions, and there is robust evidence that they prescribe more drugs from the companies with whom they interact with.

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 medical treatments. The empirical context is heart attack patients arriving at the emergency room in Florida hospitals. By combining diverse datasets and performing different empirical analysis, I find that patients treated by physicians who interact with medical device firms are more likely to receive an invasive treatment, to receive stents or to have a CABG performed.

While this paper finds no significant impact on healthcare outcomes of patients treated by physicians who interact with cardiac device companies, the findings do not allow to conclude whether these interactions are desirable. I find that different costs categories tend to be higher for treatments provided by physicians who interact with the industry, in spite of the magnitude of the coefficients being small.

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), Frakes (2012), Arlen and MacLeod (2005)). 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 13: **Regressions: Medical procedures**

Dep. var:	AvDocPay	Invasive		Stent		CABG	
	IV 1st	IV 2nd	OLS	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Av doc pay/time		0.107***	0.021***	0.014**	0.115***	0.015***	0.069***
		(0.019)	(0.006)	(0.006)	(0.022)	(0.005)	(0.018)
Av cohort pay	0.026***						
	(0.002)						
Patient characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physician characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Graduation year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HospitalxTime FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
KP F-stat		227.950			227.950		227.950
Observations	116954	116954	116958	116958	116954	116958	116954

Notes: The dependent variable *invasive* is 100 if an invasive procedure was performed and zero otherwise; similar to the dependent variables *Stents* and *CABG*. Standard errors are clustered at the physician level.

Table 14: **Regressions: Healthcare Outcomes**

Dep. var:	Died		Discharged Home		Length of Stay	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Av doc pay/time	0.000	-0.003	0.005*	0.008	0.000	0.000
	(0.001)	(0.010)	(0.003)	(0.015)	(0.000)	(0.000)
Av cohort pay						
Patient characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Physician characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Graduation year FE	Yes	Yes	Yes	Yes	Yes	Yes
HospitalxTime FE	Yes	Yes	Yes	Yes	Yes	Yes
KP F-stat		227.976		220.136		227.976
R^2	0.037	0.022	0.184	0.138	0.180	0.138
Observations	116958	116954	108382	108378	116958	116954

Notes: The dependent variables *died* and *discharged home* are 100 if the patient died in the hospital or discharged home. *Length of stay* is the log of days spent at the hospital. Standard errors are clustered at the physician level.

Table 15: **Regressions: Types of Costs**

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)
Av doc pay/time	0.000**	0.001***	0.001***	0.003***	0.001***	0.003***	0.000***	0.001***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)
Patient characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physician characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Graduation year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HospitalxTime FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.798	0.773	0.386	0.294	0.273	0.076	0.298	0.191
Observations	105568	105565	109251	109247	29957	29897	116824	116820

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 16: **Regressions: Invasive according to appropriateness**

Dep. var:	Invasive		
	Low Appropriateness	Middle Appropriateness	High Appropriateness
	(1)	(2)	(3)
Av doc pay/time	0.112**	0.131***	0.081***
	(0.043)	(0.032)	(0.017)
Patient characteristics	Yes	Yes	Yes
Doctor characteristics	Yes	Yes	Yes
Graduation year FE	Yes	Yes	Yes
Hospital x Time FE	Yes	Yes	Yes
F-test	190.198	203.901	166.572
Observations	37302	39815	39779

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 physician level.

Table 17: **Regressions: Stents according to appropriateness**

Dep. var:	Stents		
	Low Appropriateness	Middle Appropriateness	High Appropriateness
	(1)	(2)	(3)
Av doc pay/time	0.059*	0.134***	0.111***
	(0.033)	(0.035)	(0.026)
Patient characteristics	Yes	Yes	Yes
Doctor characteristics	Yes	Yes	Yes
Graduation year FE	Yes	Yes	Yes
Hospital x Time FE	Yes	Yes	Yes
F-test	190.198	203.901	166.572
Observations	37302	39815	39779

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 physician level.

Table 18: **Regressions: CABG according to appropriateness**

Dep. var:		CABG	
	Low Appropriateness	Middle Appropriateness	High Appropriateness
	(1)	(2)	(3)
Av doc pay/time	0.040*	0.101***	0.072***
	(0.021)	(0.027)	(0.019)
Patient characteristics	Yes	Yes	Yes
Doctor characteristics	Yes	Yes	Yes
Graduation year FE	Yes	Yes	Yes
Hospital x Time FE	Yes	Yes	Yes
F-test	190.198	203.901	166.572
Observations	37302	39815	39779

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 physician level.

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