



TITLE:

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Changes in industry marketing payments to physicians during the covid-19 pandemic: quasi experimental, difference-in-difference study

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ABSTRACT

OBJECTIVE To determine changes in industry marketing payments to physicians due to the covid-19 pandemic.

DESIGN Quasi experimental, difference-in-difference study.

DATA SOURCE US nationwide database of licensed physicians, the National Plan and Provider Enumeration System, which was linked to a database of industry marketing payments made to physicians, Open Payments.

POPULATION All licensed US physicians from 2018 to 2020 and those who received payments from industry.

MAIN OUTCOME MEASURES Changes in the value and the number of monthly industry payments physician received before (January-February 2020) and during the pandemic (April-December 2020) were assessed, adjusting for physicians' characteristics (gender and specialty). As the control, data for the same months in 2019 were used. Industry payments by type of payments (eg, meals, travel, consulting fees, speaker compensation, honorariums), were also examined.

RESULTS Among 880 589 US physicians included in this study, 267 463 (30.4%) physicians received a total of 4 117 482 non-research payments with \$626 million (\$710 per physician; £610; €708) in 2020 (40-44% decrease from \$1047m in 2018 and \$1115m in 2019). Industry payments decreased significantly in the months of the covid-19 pandemic (adjusted change in the value of -48.4%; 95% confidence interval -50.6 to -46.2; P<0.001; and adjusted change in the number of -47.4%, 95% confidence interval -47.7 to -47.1; P<0.001), particularly for meals and travel fees. No evidence was seen of a decrease in the number of industry payments for consulting and honorariums. A similar pattern was observed across physicians' gender and specialty. **CONCLUSIONS** Industry payments to physicians, particularly those involving physical interactions such as meals and travel, substantially decreased during the pandemic. How such changes affect prescription practices and the quality of clinical practice in the long term should be investigated.

Introduction

The covid-19 pandemic has brought unprecedented challenges to the world. In addition to the direct effect of covid-19 infection on people's health, the pandemic has had numerous spillover effects mediated through changes in lifestyle, economic burden, and disruptions of the healthcare delivery system.¹ In 2020 in the US, decreases of 12% in overall prescription volume and 37% in new prescription volume were reported, compared with those in 2019.² Although the reduction in prescriptions could be influenced by multiple factors (eg, decreased office visits,^{3 4} initiation and proliferation of telemedicine,^{3 4} decreased prevalence of other communicable diseases,⁵ and restrained health seeking behavior⁶ during the pandemic), the underlying reasons for the change in physicians' prescription behavior during the pandemic have not been fully elucidated.

One potential mechanism might be related to disruptions in the direct relations between the pharmaceutical industry and individual physicians. Since the establishment of the Open Payments program in 2013 under the *Physician Payment Sunshine Act*,⁷ ample evidence has shown that receipt of industry marketing payments influences physicians' medication prescribing practices and increases the associated healthcare costs.⁸⁻¹² This financial competing interest has been scrutinized heavily worldwide by policy makers and public health leaders alike, given the possibility of inappropriately

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Financial relations between industry and physicians can influence clinical practice and physician prescription patterns
- ⇒ Some industry marketing involves physical interactions with physicians, the covid-19 pandemic might have altered the patterns of industry payments to physicians
- ⇒ What remains unknown, however, is whether and how the financial relations between industry and physicians have changed during the covid-19 pandemic

WHAT THIS STUDY ADDS

- ⇒ Across 880 589 physicians from a nationally representative database of industry marketing payments to physicians, the value and the number of industry payments to US physicians decreased substantially during the pandemic across all specialties, particularly those involving physical interactions, such as meals and travel fees
- ⇒ These results indicate that the pandemic affected the financial association between physicians and the pharmaceutical industry

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE, OR POLICY

- ⇒ These difference-in-difference analyses highlight the importance to assess how the decline in industry payments during the pandemic could have influenced subsequent prescription patterns and patient outcomes, which should be the subject of future research
- ⇒ Close monitoring of whether the financial relations between industry and physician will return to the prepandemic state or whether some of these changes become permanent



influencing clinical decision making among physicians for monetary gain.^{13 14} Despite widespread concern and criticism, one study has shown that the amount of marketing payments related to the industry has remained stable between 2014 and 2018,¹⁵ indicating that increased transparency might not be sufficient to change physicians' financial relations with the industry.

The covid-19 pandemic, however, substantially altered the healthcare delivery system and the associated activities that physicians normally engage in, such as local and national medical conferences, continuing medical education activities, and academic detailing events. To date, how this disruption might have influenced the interaction between the pharmaceutical industry and individual physicians is unclear. Physician and industry financial relations could have been drastically affected during the covid-19 pandemic, which could have led to a number of potential consequences, including the reduction of both appropriate and inappropriate medication prescriptions by individual physicians. This possible influence of industry payments on physician practicing behavior means that understanding how these financial associations have (or have not) changed during the covid-19 pandemic is critically important.

Therefore, using a national database of US physicians, we examined changes in the value and the number of industry payments made to physicians associated with the covid-19 pandemic compared with the prepandemic baseline using a quasi experimental, difference-in-difference study design. Given the heterogeneous role of each type of payment (eg, meals, travel, consulting fees, speaker compensation, honorariums), we also examined changes in industry payments by the type of payments. Furthermore, because the financial relations between physician and industry might vary by physicians' gender and specialties,¹⁶⁻¹⁸ we investigated whether changes in industry payments due to the pandemic vary by physicians' gender and specialty.

Methods

Data sources

We matched the Centres for Medicare and Medicaid Services' Open Payments databases in 2018-2020¹⁹ to its National Plan and Provider Enumeration System (NPPES) database²⁰ and collated physicians' full name and the zip code for the primary practice location, as previous studies have done.^{16 18}

Physician characteristics

We extracted information on physicians' gender (male and female), specialty (taxonomy code), and practice location (US state) from the NPPES database. Physician specialty was classified into 32 categories; four in primary care physicians (internal medicine, family medicine, pediatrics, and hospitalist), nine in surgeons (obstetrics and gynecology, general, orthopedic, otolaryngology, urology, neurosurgery, plastic, thoracic and

vascular, and colorectal), 18 in specialists (emergency medicine, psychiatry, anesthesiology, radiology, cardiology, ophthalmology, pediatric specialty, neurology, rehabilitation, dermatology, gastroenterology, hematology and oncology, nephrology, pulmonology, infectious diseases, endocrinology, rheumatology, and allergy and immunology), and one called others (eg, surgical oncology, oral surgery, radio oncology, pathology, and nuclear medicine). As a result of the variation of stay-at-home orders across states during the pandemic,²¹ information about practice location by state was also extracted from the NPPES database.

Payment data

We identified all non-research payments to physicians, which included non-research forms of payment such as meals, travel, consulting fees, speaker compensation, honorariums, and others (education, grant, gifts, entertainment, and space rental or facility fees). Research payments, royalty or license payments, and ownership interests, such as stocks and partnership shares, were not included in this analysis because these payments were not likely to be targeted to specific drugs at a specific time point. Payments are presented in nominal US dollars.

Statistical analysis

First, we examined the trends in the value and the number of industry payments between 2018 and 2020, according to the type of payments (ie, meals, travel, consulting, speaking fee, honorariums, and others). We then used a quasi experimental, difference-in-difference method^{22 23} to investigate changes in monthly industry payments due to the covid-19 pandemic. We compared before the pandemic (January-February 2020) to after (April-December 2020; March 2020 was excluded as the transition period) in 2020, using the same period in 2019 as the control, adjusting for physician characteristics (ie, gender, specialty, and US state). The changes in outcomes attributable to the covid-19 pandemic were represented by regression coefficients of the interaction terms between the year indicator (ie, 2019 v 2020) and the month indicator (ie, January-February v April-December) in the multivariable negative binomial models (to account for the distribution skewed to the right of the value and the number of industry payments). In all models, we adjusted for physicians' gender, specialty, and the state in which the practice is located. We report difference-in-difference estimates in relative percentage changes as well as absolute changes in outcomes using average marginal effects. We found the average marginal effects by calculating the differences in predicted outcomes at each level of the interaction terms for each observation and averaging over the entire sample.²⁴ The parallel trend assumption of the difference-in-difference model was formally tested.

Each type of industry marketing payment requires different resources and might have different influences



on clinical practice,^{25 26} therefore, we stratified analyses by the type of payments (meals, travel, consulting fees, speaker compensation, honorariums, and others). Because the receipt of industry marketing payments also varies depending on physicians' characteristics,¹⁶⁻¹⁸ we also stratified our analyses by physicians' gender and specialties. Additionally, to assess whether the trends in industry payments during the pandemic vary by geographical regions, we stratified analyses by the four main areas (northeastern, midwestern, southern, and western regions) in the US according to the Census Bureau.²⁷ P values were adjusted for multiple comparisons using the Benjamini-Hochberg method.²⁸ Statistical analyses were done with Stata software version 16.0 (StataCorp, TX).

Sensitivity analysis

To evaluate the robustness of our findings, we carried out three main sensitivity analyses. We used the mean value and number of payments in 2018 and 2019 (instead of 2019 only) as the control group. We reanalyzed the data using ordinary least squares regression models with Huber-White robust standard errors adjusting for physicians' characteristics. We also used the event study design^{23 29} to compare the change in the value and the number of industry marketing payments in the event year with the previous year as the control year. In the event study design, we used the multivariable negative binomial models, including indicator variables for time (reference category was defined as February—ie, a month before the event), a binary variable for the intervention year group (2018-19 v 2019-20), the interaction term between these two regressors, and physicians' characteristics.

Patient and public involvement

No patients were involved in setting the research question or the outcome measures, nor were they involved in developing plans for design or implementation of the study. No patients were asked to advise on interpretation or writing up of results. We have no plans to disseminate the results of the research to study participants or the relevant patient community.

Results

Physician characteristics

Across 1 029 149 physicians in the merged database, we excluded 148 541 physicians without information about practice location in the US. Of 785 237 physicians were unmatched in the Open Payments Profile database. We also excluded 19 physicians who received industry payments of more than \$1 million (£850 000; €1 005 000) within a month (as outliers), resulting in the final analytical sample of 880 589 physicians. The flow of sample selection for the study is provided in online supplemental figure A. Among 880 589 physicians included in our study, 63.7% were men, 38.2% were primary

care physicians, 16.8% were surgeons, and 39.5% were specialists (table 1). Surgeons and most of the specialists (except emergency medicine, psychiatry, anesthesiology, radiology, pediatric specialty, and rehabilitation) were likely to receive industry payments across 2018-20 (ie, they showed a larger proportion among physicians who received industry payments than the proportion among physicians in each specialty in the NPPES database). The distribution of physicians' gender and specialty among physicians who received industry payments was similar across the study period.

Industry payments between 2018 and 2020

In 2020, 267 463 physicians in the US received 4 117 482 non-research payments (except royalty, license, and ownership interests) to the value of \$626m, which was a 40-44% reduction from \$1115m in 2019 and \$1047m in 2018 (table 2). From 2018 to 2020, meals constituted 90% of the total number of industry payments, and speaking fees constituted the largest value of payments (35-38%). The proportion of travel fees decreased in 2020 compared with previous years for both the number (5.1% in 2018, 5.6% in 2019, and 2.7% in 2020) and the value (12.1% in 2018, 12.4% in 2019, and 5.0% in 2020) of payments.

Change in the value of industry payments

The unadjusted monthly trends in the value of industry payments between 2018 and 2020 are shown in figure 1 (top panel). The results of the tests for the parallel trend assumption can be found in online supplemental table A. We found a significant decline in the monthly value of payments due to the covid-19 pandemic (adjusted percentage change of -48.4%; 95% confidence interval -50.6% to -46.2%; P<0.001; and adjusted absolute change of -\$75.7, 95% confidence interval -81.2 to -70.3; P<0.001; table 3). We also found a significant reduction in the value of payments during the pandemic across any types of payments except others (table 3, online supplemental figure B). We found no evidence that changes in the value of payments due to the pandemic varied by gender (online supplemental table B). When we stratified by physicians' specialty, the change was noted across all specialties, with the largest reduction among neurologists and rheumatologists on both the relative and the absolute scales compared with internal medicine physicians. The decline in the value of industry payments was consistently found across all regions in the US (online supplemental table C).

Changes in the number of industry payments

The unadjusted monthly trends in the number of industry payments between 2018 and 2020 are shown in figure 1 (bottom panel).



Table 1 | Physician characteristics in the NPPES database and who received payments shown from the Open Payments database. Data are number (%) of physicians (%) unless stated otherwise

Physician characteristics and specialty	Total No of physicians in NPPES	No of physicians who received industry payments between 2018 and 2020		
		2018	2019	2020
No of physicians	880 589	350 718	345 989	267 805
Gender:				
Male	560 707 (63.7)	239 835 (68.4)	235 633 (68.1)	185 879 (69.4)
Female	319 882 (36.3)	110 883 (31.6)	110 356 (31.9)	81 926 (30.6)
Primary care:				
Internal medicine	140 202 (15.9)	54 336 (15.5)	53 590 (15.5)	41 719 (15.6)
Family medicine	123 661 (14.0)	46 804 (13.4)	45 110 (13.0)	34 870 (13.0)
Pediatrics	62 959 (7.2)	21 030 (6.0)	20 362 (5.9)	14 642 (5.5)
Hospitalist	9307 (1.1)	2780 (0.8)	2925 (0.9)	2119 (0.8)
Surgery:				
Obstetrics/gynecology	44 310 (5.0)	21 629 (6.2)	21 107 (6.1)	16 375 (6.1)
General	36 635 (4.2)	17 934 (5.1)	17 966 (5.2)	14 187 (5.3)
Orthopedic	28 274 (3.2)	17 362 (5.0)	17 453 (5.0)	14 675 (5.5)
Otolaryngology	11 138 (1.3)	6056 (1.7)	6105 (1.8)	4707 (1.8)
Urology	10 941 (1.2)	6780 (1.9)	6693 (1.9)	5699 (2.1)
Neurosurgery	5921 (0.7)	3455 (1.0)	3434 (1.0)	2882 (1.1)
Plastic	4855 (0.6)	2945 (0.8)	2932 (0.9)	2376 (0.9)
Thoracic and vascular	3920 (0.5)	2292 (0.7)	2246 (0.7)	1892 (0.7)
Colorectal	1251 (0.1)	781 (0.2)	776 (0.2)	620 (0.2)
Specialists:				
Emergency medicine	53 637 (6.1)	11 340 (3.2)	11 380 (3.3)	7867 (2.9)
Psychiatry	52 469 (6.0)	15 270 (4.4)	15 084 (4.4)	10 793 (4.0)
Anesthesiology	42 482 (4.8)	13 379 (3.8)	13 391 (3.9)	8918 (3.3)
Radiology	30 373 (3.5)	7325 (2.1)	7303 (2.1)	4857 (1.8)
Cardiology	22 362 (2.5)	14 716 (4.2)	14 402 (4.2)	12 438 (4.6)
Ophthalmology	20 781 (2.4)	11 969 (3.4)	12 013 (3.5)	10 388 (3.9)
Pediatric specialty	19 239 (2.2)	5617 (1.6)	5523 (1.6)	3637 (1.4)
Neurology	15 677 (1.8)	7948 (2.3)	7979 (2.3)	6334 (2.4)
Rehabilitation	14 016 (1.6)	3945 (1.1)	3842 (1.1)	2833 (1.1)
Dermatology	13 669 (1.6)	7791 (2.2)	7805 (2.3)	6682 (2.5)
Gastroenterology	12 906 (1.5)	8262 (2.4)	7926 (2.3)	6635 (2.5)
Hematology and oncology	11 527 (1.3)	6732 (1.9)	6472 (1.9)	5368 (2.0)
Nephrology	8457 (1.0)	4786 (1.4)	4833 (1.4)	3828 (1.4)
Pulmonology	7289 (0.8)	4041 (1.2)	3977 (1.2)	3386 (1.3)
Infectious diseases	6065 (0.7)	2512 (0.7)	2491 (0.7)	1957 (0.7)
Endocrinology	5910 (0.7)	3359 (1.0)	3275 (1.0)	2679 (1.0)
Rheumatology	4794 (0.5)	2749 (0.8)	2651 (0.8)	2249 (0.8)
Allergy and immunology	4240 (0.5)	2407 (0.7)	2335 (0.7)	1975 (0.7)
Others*	51 322 (5.8)	12 386 (3.5)	12 608 (3.6)	8218 (3.1)

NPPES=National Plan and Provider Enumeration System.
*Others include surgical oncology, oral surgery, radio oncology, pathology, and nuclear medicine.

We found a significant decline in the monthly number of payments per 100 physicians due to the covid-19 pandemic (adjusted percentage change of -47.4% ; 95% confidence interval -47.7 to -47.1 ; $P < 0.001$; and adjusted absolute change of -43.6 , 95% confidence interval -44.2 to -43.0 ; $P < 0.001$; table 3). Although we found a significant reduction in the number of payments, particularly for meals, travel fees, and speaking fees, the reduction was not observed for consulting and honorariums (table 3, online supplemental figure C). We found no evidence

that changes in the number of payments due to the pandemic varied by gender (online supplemental table D). When we stratified by physicians' specialty, most surgeons and specialists, except rehabilitation physicians and pulmonologists, showed a larger reduction on the relative scale during the pandemic compared with physicians in internal medicine (a specialty with the highest proportion among US physicians). The reduction in the number of industry payments was consistently noted across all regions in the US (online supplemental table C).



Table 2 | Changes in industry payments to physicians between 2018 and 2020

Types of industry payments	2018	2019	2020
Total*			
No of physicians	350 520	345 789	267 463
No of payments	7 761 986	7 492 724	4 117 482
Total payment value	\$1047 million	\$1115 million	\$626 million
Type of non-research payments			
Meals:			
No of physicians	342 178	337 595	254 448
No (%) of payments	6 915 047 (89.1)	6 642 500 (88.7)	3 710 716 (90.1)
Total payment value (% of main total)	\$162 million (15.5)	\$163 million (14.6)	\$78 million (12.5)
Travel:			
No of physicians	44 709	45 458	20 204
No (%) of payments	396 793 (5.1)	422 708 (5.6)	112 314 (2.7)
Total payment value (% of main total)	\$127 million (12.1)	\$138 million (12.4)	\$31 million (5.0)
Consulting:			
No of physicians	21 242	23 435	19 054
No (%) of payments	96 215 (1.2)	99 859 (1.3)	93 460 (2.3)
Total payment value (% of main total)	\$290 million (27.7)	\$305 million (27.4)	\$240 million (38.3)
Speaking fee			
No of physicians	21 947	20 172	16 317
No (%) of payments	174 745 (2.3)	179 202 (2.4)	128 550 (3.1)
Total payment value (% of main total)	\$393 million (37.5)	\$421 million (37.8)	\$217 million (34.7)
Honorariums			
No of physicians	3812	4331	3548
No (%) of payments	10 733 (0.1)	12 782 (0.2)	10 367 (0.3)
Total payment value (% of main total)	\$27 million (2.6)	\$31 million (2.8)	\$19 million (3.0)
Other†			
No of physicians	79 718	76 435	43 983
No (%) of payments	168 453 (2.2)	135 673 (1.8)	62 075 (1.5)
Total payment value (% of main total)	\$47 million (4.5)	\$57 million (5.1)	\$40 million (6.4)

\$1.00=£0.86; €1.00.
 *Research payments, royalty, or license, and ownership interests such as stocks and partnership shares were not included in this analysis.
 †Others include education, grant, gifts, entertainment, and space rental or facility fees.

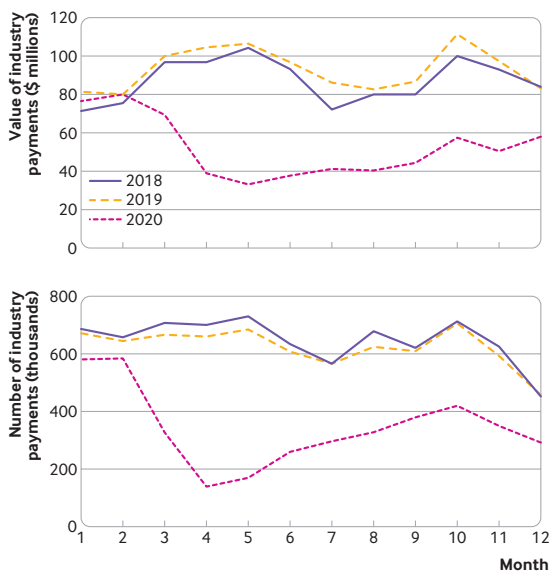


Figure 1 | Overall monthly trends in the value and number of industry payments to physicians between 2018 and 2020. \$1.00=£0.86; €1.00

Sensitivity analyses

The results did not qualitatively change when we used the average value and number of payments in 2018 and 2019 instead of 2019 only (online supplemental table E) and when we reanalyzed the data using ordinary least squares instead of the negative binomial model (online supplemental table F). Our findings were also supported by the event study design, which provided visual evidence to show that the industry marketing payments dropped at the event month (ie, pandemic in March 2020; figure 2).

Discussion

Principal findings

Using national data for industry marketing payments to US physicians, we found that the value and the number of the payments significantly declined by almost half during the covid-19 pandemic. A similar pattern was observed across physicians' gender, all specialties, and regions in the US. To our knowledge, this study is the first to elucidate how the covid-19 pandemic has changed the relations between industry and

Table 3 | Difference-in-difference estimates of adjusted change in value and number of industry payments per physician during the covid-19 pandemic (ie, January-February v April-December in 2020) compared with 2019 according to the type of payments

Type of payment	Value of industry payments per physician (95% CI)			No of industry payments per 100 physicians (95% CI)		
	Relative % change	Absolute \$ change	Adjusted P value	Relative % change	Absolute change	Adjusted P value
Total	-48.4 (-50.6 to -46.2)	-75.7 (-81.2 to -70.3)	<0.001	-47.4 (-47.7 to -47.1)	-43.6 (-44.2 to -43.0)	<0.001
Meal	-63.9 (-64.3 to -63.5)	-14.9 (-15.1 to -14.7)	<0.001	-46.0 (-46.3 to -45.7)	-37.0 (-37.5 to -36.5)	<0.001
Travel	-93.8 (-94.3 to -93.3)	-19.3 (-20.4 to -18.2)	<0.001	-91.5 (-91.9 to -91.0)	-5.9 (-6.1 to -5.7)	<0.001
Consulting	-15.7 (-23.5 to -6.9)	-6.7 (-10.8 to -2.7)	<0.001	6.6 (1.8 to 11.6)	0.1 (0.0 to 0.1)	0.01
Speaking fee	-36.3 (-41.4 to -30.7)	-13.1 (-15.7 to -10.5)	<0.001	-34.4 (-36.8 to -31.8)	-0.9 (-0.9 to -0.8)	<0.001
Honorariums	-48.5 (-55.9 to -39.9)	-2.3 (-2.9 to -1.7)	<0.001	7.9 (-28.8 to 63.5)	0.0 (-0.1 to 0.1)	0.72
Others	-12.0 (-29.8 to 10.4)	-1.1 (-2.8 to 0.6)	0.27	-25.7 (-28.7 to -22.6)	-0.1 (-0.1 to 0.0)	<0.001

Difference-in-difference estimates in relative percentage changes were calculated by regression coefficients of the interaction terms between the year indicator (ie, 2019 v 2020) and the month indicator (ie, January-February v April-December) in the multivariable negative binomial models adjusting for physicians' gender, specialty, and practice location. The adjusted absolute changes in outcomes were estimated by calculating the differences in predicted outcomes at each level of the interaction terms for each observation and averaging over the entire sample. P value was adjusted for multiple comparisons using the Benjamini-Hochberg method.
CI=confidence interval.

physicians. Given that the reduction in these payments was the largest among those related to meals and travel fees, this effect was observed partially due to restricted in-person interactions during the pandemic. Our findings should be informative for policy makers interested in understanding the financial association between industry and physicians, and how these changes might eventually affect individual physicians' prescription practice and patient outcomes, which should be the subject of future research.

The possible influence of the financial association between the pharmaceutical industry and physicians

has received great concern,³⁰ mainly because inappropriate prescriptions could have been introduced through misguided information and potential financial competing interests. For example, a previous study showed that physicians who received meals sponsored by the pharmaceutical industry were more likely to prescribe brand name drug than generic alternatives.³¹ Additionally, the receipt of the industry payments related to opioids was associated with increased prescription of opioids and opioid overdose deaths, indicating the possible over prescription of opioids related to the industry marketing.³²⁻³⁴ However, industry marketing to physicians might also have positive aspects related to continuing medical education activities. Across the US, the pharmaceutical industry often engages and supports the provision of educational opportunities for physicians to obtain the latest evidence on old and new drugs. For example, a previous work focusing on a new cardiovascular drug that was under strict prior-authorization requirements indicated that industry marketing to physicians might have contributed to facilitating the judicious and early adoption of the high-cost but effective drugs as a key driver of their prescribing behavior.²⁶

Of note, we found the largest reduction in the value and the number of industry payments in the form of meals and travel fees during the pandemic. Previous studies have consistently shown that meals constituted more than 90% of the total number of industry payments.^{11 26} These studies suggested that encounters with industry marketing, even in the inexpensive form of meals, drive prescriptions, possibly through educational opportunities, drive sharing updated information on the drug, and improve physicians' familiarity with the drug.^{11 26 31} Our findings indicate that these educational opportunities have been reduced due to the physical restrictions enforced during the pandemic and cancellations of local and national

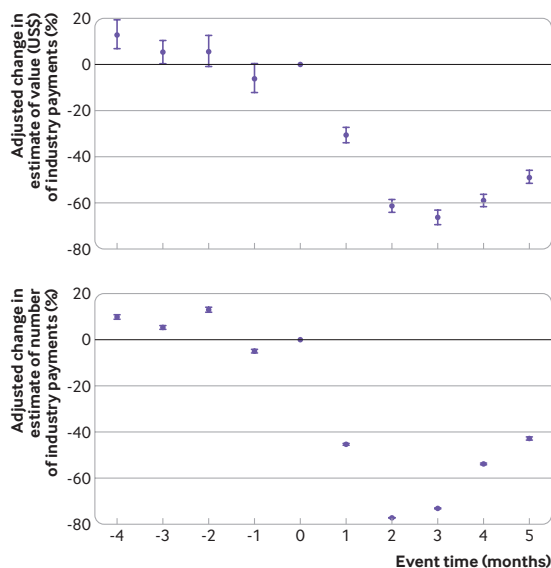


Figure 2 | Adjusted change (%) in estimates of the value and the number of industry payments per physician between 2018-19 and 2019-20 before and after the pandemic. The intervention year was 2019-20, and the control period included 2018-19. Reference of event time was set to February (a month before the pandemic in 2020). Multivariable negative binomial regression models were used to calculate percentage change in the estimate (ie, (coefficient-1)×100) adjusting for physicians' gender, specialty, and practice location



medical conferences. Although a decrease in revenues could also be a reason for decreased marketing, the average profit margin of pharmaceutical industries did not decrease during the pandemic.³⁵ Because this trend might be affected by profits related to covid-19 for some specific pharmaceutical organizations, future research is needed to assess whether and to what extent the change in revenues of each organization influences their financial relations with physicians.

We did not find a reduction in the number of payments for consulting and honorariums. These payments do not necessarily require physical interactions between the pharmaceutical industry and physicians. Because consulting and honorariums are likely to be targeted to key opinion leaders (whereas meals are generally targeted to a broad type of physicians), the possible influence of the pandemic on prescription patterns through reduced industry marketing payments needs to be carefully assessed and monitored according to physicians' role in academia or clinical practice.

The reduction in industry payments during the pandemic was consistently observed, even when categorized by physician gender and across all physician specialties and geographical regions in the US. Although the absolute reductions in the value and the number of payments were larger in male physicians than in female physicians, this amount is probably because male physicians are generally more likely to receive industry payments than female physicians at baseline (ie, before the pandemic),^{16–18} and the relative reduction was similar between physicians' gender. Our consistent findings of the stratified analyses by physician specialties indicate that the pandemic has influenced the interaction between the pharmaceutical industry and individual physicians regardless of their specialties.

Limitations of the study

Our study has limitations. First, although we used the nationwide database of licensed US physicians (NPPES), the matching rate of physicians in the Open Payments database to the NPPES database was 88%; thus, we might not be able to capture all physicians who received industry marketing payments in the US. Second, measurement error is a possibility due to misreporting or under-reporting of payments. However, this bias would be small given the effort by the Centres for Medicare and Medicaid Services to improve the accuracy of the Open Payments data (eg, encouraging all physicians to review the information, facilitating education activities to increase awareness of the program), making the database comprehensive and reliable.⁷ Third, because the present study focused on non-research payments, our findings might not be generalizable to other forms of payments such as ownership interests, royalty, and license payments. These types of payments are targeted to a small number of physicians¹⁸ and not specific to a drug at a specific time,¹⁹ thus beyond the scope of this study. Finally, because data for physicians' prescription

and patients' outcomes during the covid-19 pandemic are not publicly available yet, we could not evaluate these outcomes via the decreased industry marketing payments, which should be the subject of future research.

Conclusions

Using a nationally representative database of US physicians, we found that the pharmaceutical industry marketing payments to physicians, particularly those involving physical interactions such as meals and travel fees, substantially decreased during the covid-19 pandemic. Our findings highlight the need to closely monitor how this might have influenced subsequent prescription patterns, physicians' medical education on drug related evidence to date, and, importantly, patient outcomes. Policy makers and public health leaders must continue to monitor whether the financial relations between industry and physician will return to the prepandemic state as the covid-19 pandemic eases or whether some of these changes will become permanent.

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Contributors KI and YT conceived the concept and design. KI, JFF, NK, and YT were responsible for acquisition, analysis, or interpretation of data. KI and YT drafted the manuscript. KI, JFF, NK, and YT critically revised the manuscript for important intellectual content. KI is the guarantor and takes responsibility for the integrity of the data and the accuracy of the data analysis. The authors assume full responsibility for the accuracy and completeness of the ideas presented. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. Transparency: The lead author (the manuscript's guarantor) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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Supplemental Materials

Changes in Industry Marketing Payments to Physicians during the COVID-19 pandemic

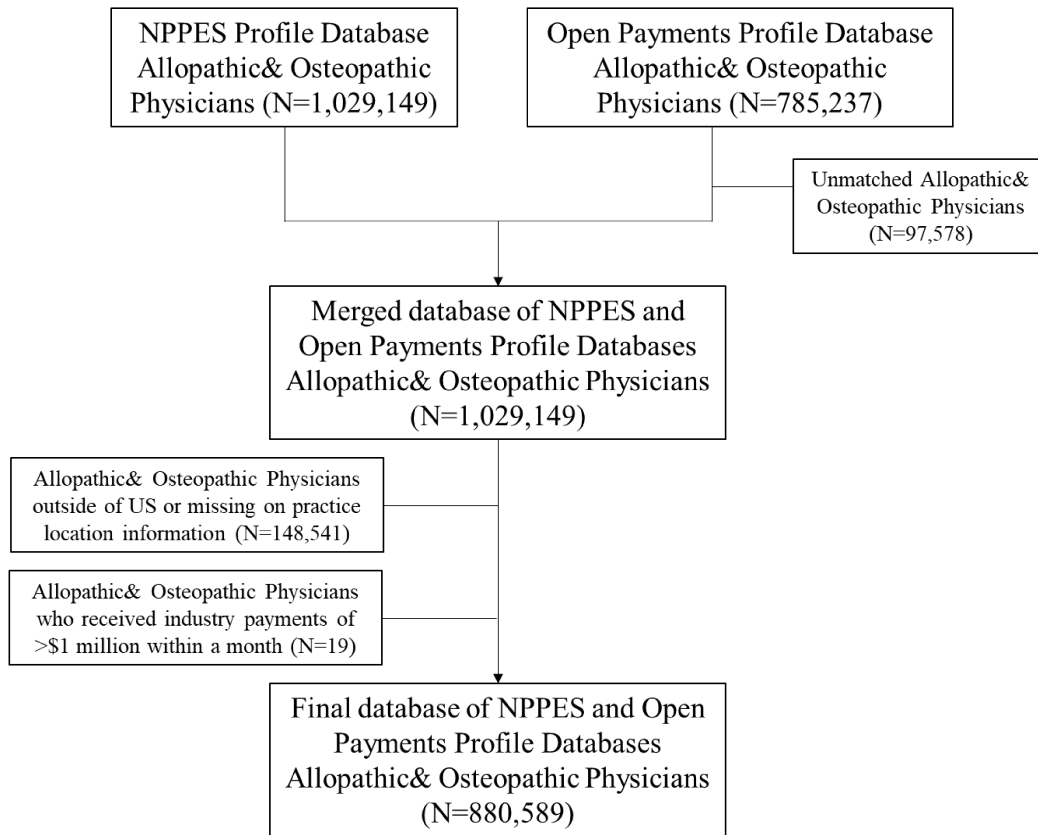
Supplementary Figures

- A. Flow of study sample selection.
- B. Monthly trends in the value of industry payments between 2018 and 2020 according to the type of payments.
- C. Monthly trends in the number of industry payments between 2018 and 2020 according to the type of payments.

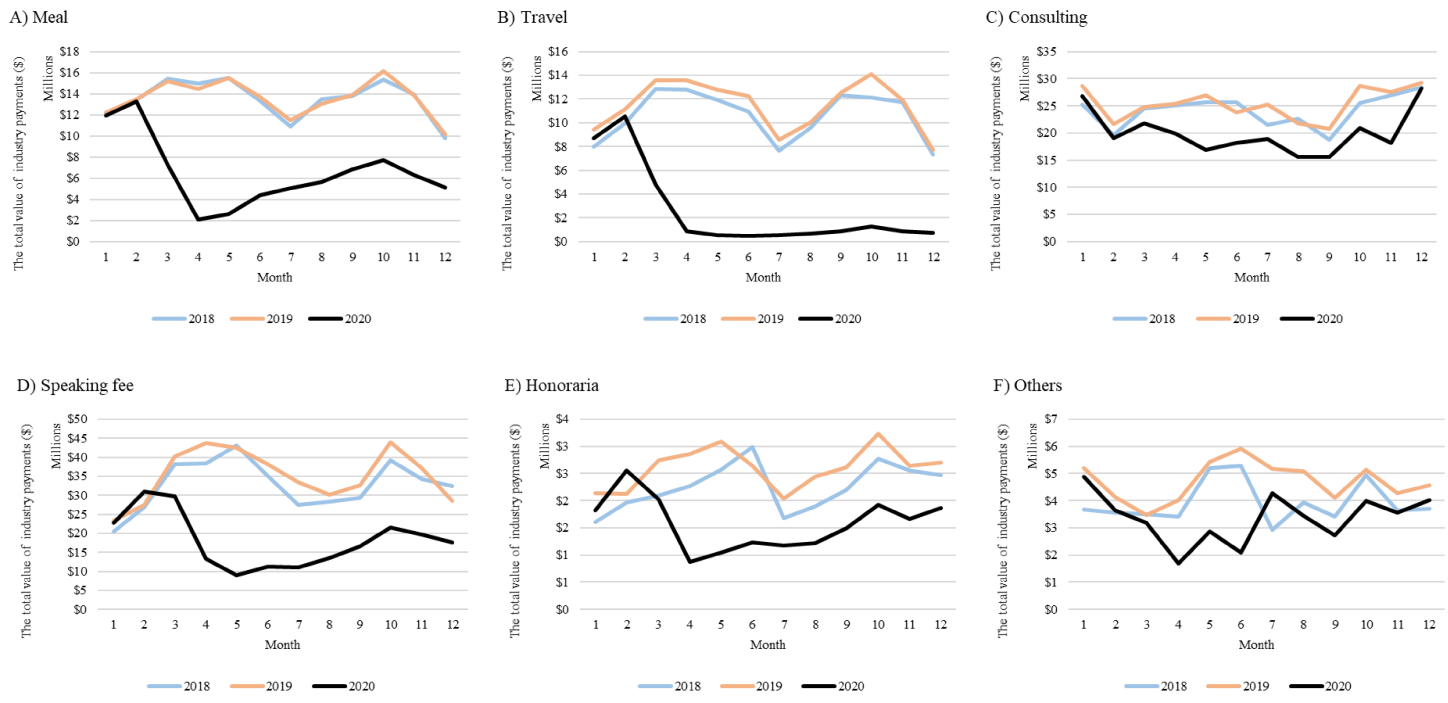
Supplementary Tables

- A. Test of parallel trend assumption
- B. Change in the value of industry payments per physician during the COVID-19 pandemic (i.e., April-December vs. January-February in 2020) compared to 2019 according to physicians' gender and specialty.
- C. Change in value and number of industry payments per physician during the COVID-19 pandemic (i.e., January-February vs. April-December in 2020) compared to 2019 according to the four regions in the US.
- D. Change in the number of industry payments per physician during the COVID-19 pandemic (i.e., April-December vs. January-February in 2020) compared to 2019 according to physicians' gender and specialty.
- E. Change in value and number of industry payments per physician during the COVID-19 pandemic (i.e., January-February vs. April-December in 2020) compared to the average outcomes in 2018 and 2019 according to the type of payments.
- F. Change in value and number of industry payments per physician during the COVID-19 pandemic (i.e., January-February vs. April-December in 2020) compared to 2019 according to the type of payments using ordinary least squares regression models.

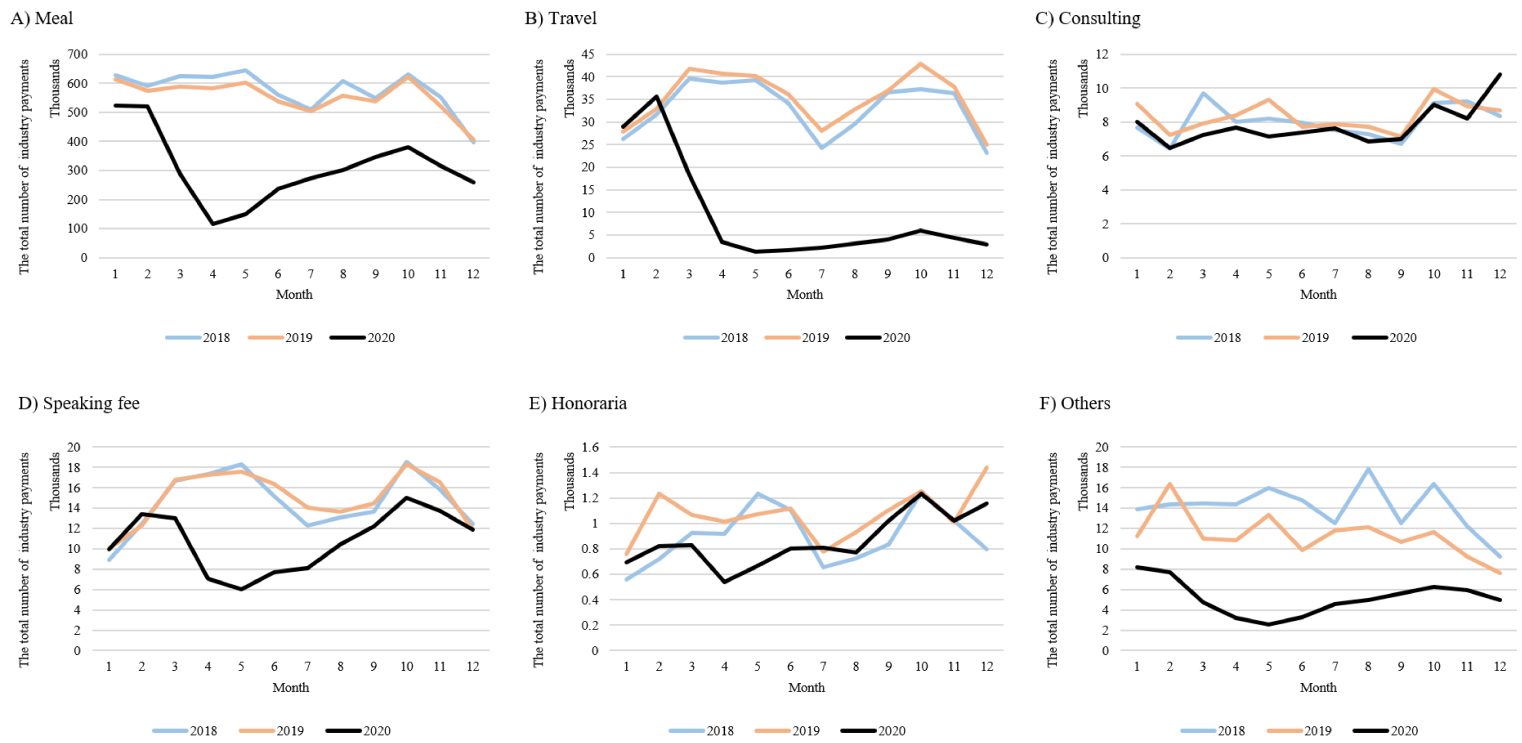
Supplementary figure A. Flow of study sample selection



Supplementary figure B. Monthly trends in the value of industry payments between 2018 and 2020 according to the type of payments



Supplementary figure C. Monthly trends in the number of industry payments between 2018 and 2020 according to the type of payments



Supplementary table A. Test of parallel trend assumption

Outcome	Interaction term between the monthly trend and the year indicator (i.e., 2019 vs. 2020)	
	Coefficient estimate [95% CI]	P-value
Value of industry payments	0.97 (0.95 to 1.00)	0.08
Number of industry payments	0.946 (0.942 to 0.949)	<0.05

Notes: We used negative binomial regression models with an interaction term between the month trend variable (continuous from December to February) and the year indicator (i.e., 2019 vs. 2020) during the baseline period (December in a prior year to February). Although p-values were small due to the large sample size (≈ 0.9 million), the point estimates were close to 1.0 (i.e., parallel).

Supplementary table B. Change in the value of industry payments per physician during the COVID-19 pandemic (i.e., April-December vs. January-February in 2020) compared to 2019 according to physicians' gender and specialty.

Physician characteristics	Difference-difference estimates (95% CI) of the value of industry payments per physician		
	Relative % change	Absolute \$ change	p-for-interaction ^a
Gender			
Male	-49.5 (-51.6 to -47.3)	-96.6 (-103.8 to -89.4)	ref
Female	-47.9 (-52.0 to -43.5)	-38.0 (-43.3 to -32.7)	0.14
Specialty			
Primary Care			
Internal Medicine	-45.8 (-52.5 to -38.2)	-49.0 (-60.5 to -37.5)	ref
Family Medicine	-35.3 (-41.8 to -28.0)	-11.4 (-15.1 to -7.7)	0.08
Pediatrics	-38.0 (-57.6 to -9.4)	-8.9 (-15.0 to -2.8)	0.58
Hospitalist	-61.4 (-73.7 to -43.6)	-19.3 (-27.3 to -11.3)	0.29
Surgery			
Obstetrics/Gynecology	-51.1 (-60.3 to -39.6)	-35.6 (-51.5 to -19.7)	0.43
General	-54.7 (-59.6 to -49.2)	-108.2 (-126.3 to -90.1)	0.03
Orthopedic	-52.3 (-56.1 to -48.1)	-224.5 (-258.5 to -190.5)	0.12
Otolaryngology	-55.5 (-65.2 to -42.9)	-56.6 (-75.7 to -37.4)	0.95
Urology	-63.6 (-69.9 to -55.9)	-163.8 (-202.9 to -124.6)	<0.001
Neurosurgery	-51.3 (-61.3 to -38.7)	-205.5 (-284.3 to -126.6)	0.51
Plastic	-53.0 (-68.3 to -30.4)	-97.7 (-158.8 to -36.5)	0.52
Thoracic/Vascular	-49.5 (-58.8 to -38.0)	-187.8 (-255.2 to -120.5)	0.60
Colorectal	-62.2 (-72.3 to -48.4)	-180.0 (-257.6 to -102.4)	0.12
Specialists			
Emergency Medicine	-51.1 (-63.8 to -34.0)	-24.8 (-37.3 to -12.4)	0.58
Psychiatry	-72.2 (-76.0 to -67.7)	-126.1 (-146.4 to -105.7)	<0.001
Anesthesiology	-46.9 (-56.5 to -35.2)	-22.0 (-32.0 to -12.1)	0.58
Radiology	-18.5 (-32.7 to -1.4)	-21.1 (-40.3 to -1.8)	0.01
Cardiology	-48.8 (-53.9 to -43.2)	-165.8 (-192.7 to -138.9)	0.43
Ophthalmology	-58.5 (-64.6 to -51.5)	-139.2 (-168.8 to -109.7)	0.06
Pediatric Specialty	-55.2 (-66.9 to -39.2)	-63.6 (-94.5 to -32.7)	0.34
Neurology	-69.5 (-72.4 to -66.3)	-489.8 (-547.2 to -432.5)	<0.001
Rehabilitation	-59.3 (-68.2 to -47.9)	-50.7 (-72.1 to -29.2)	0.06
Dermatology	-50.0 (-55.5 to -43.8)	-196.0 (-241.7 to -150.4)	0.29
Gastroenterology	-57.5 (-63.3 to -50.8)	-109.5 (-135.8 to -83.3)	0.03
Hematology/Oncology	-37.8 (-46.8 to -27.3)	-195.1 (-260.6 to -129.6)	0.55
Nephrology	-48.1 (-61.8 to -29.5)	-79.3 (-114 to -44.6)	0.51
Pulmonology	-55.5 (-64.0 to -45.0)	-155.9 (-201.7 to -110.1)	0.12
Infectious Diseases	-63.8 (-70.9 to -55.0)	-222.7 (-275.7 to -169.7)	0.01
Endocrinology	-45.6 (-51.4 to -39.0)	-271.5 (-345.0 to -198.0)	0.79
Rheumatology	-62.6 (-67.2 to -57.4)	-483.8 (-574.1 to -393.5)	<0.001
Allergy/Immunology	-38.8 (-53.2 to -20.0)	-98.8 (-185.2 to -12.5)	0.51
Others	-20.1 (-36.0 to -0.1)	-18.1 (-39.1 to -2.9)	<0.001

^aP-value (adjusted for multiple comparisons using the Benjamini-Hochberg method) of the multiplicative 3-way interaction term between i) the year indicator (i.e., 2019 vs. 2020), ii) the month indicator (i.e., January-February vs. April-December), and iii) gender or specialty.

Supplementary table C. Change in value and number of industry payments per physician during the COVID-19 pandemic (i.e., January-February vs. April-December in 2020) compared to 2019 according to the four regions in the US.

Type of payments	Difference-in-difference estimates (95% CI) of the value of industry payments per physician			Difference-in-difference estimates (95% CI) of the number of industry payments per 100 physicians		
	Relative % change	Absolute \$ change	Adjusted p-value	Relative % change	Absolute change	Adjusted p-value
Total	-48.4 (-50.6 to -46.2)	-75.7 (-81.2 to -70.3)	<0.001	-47.4 (-47.7 to -47.1)	-43.6 (-44.2 to -43.0)	<0.001
Northeast	-47.0 (-51.4 to -42.2)	-68.4 (-77.9 to -59.0)	<0.001	-51.7 (-52.4 to -51.0)	-40.2 (-41.4 to -39.0)	<0.001
Midwest	-51.9 (-54.6 to -49.0)	-83.9 (-92.3 to -75.4)	<0.001	-42.4 (-43.0 to -41.9)	-47.7 (-48.9 to -46.6)	<0.001
South	-47.5 (-52.0 to -42.6)	-72.9 (-85.0 to -60.8)	<0.001	-46.9 (-47.7 to -46.1)	-35.9 (-37.2 to -34.7)	<0.001
West	-44.2 (-52.1 to -34.9)	-49.8 (-68.2 to -31.4)	<0.001	-42.6 (-44.2 to -40.9)	-43.1 (-46.0 to -40.2)	<0.001

Four regions (Northeast, Midwest, South, and West) were defined according to the Census Bureau. Difference-in-difference estimates in relative percentage changes were calculated by regression coefficients of the interaction terms between the year indicator (i.e., 2019 vs. 2020) and the month indicator (i.e., January-February vs. April-December) in the multivariable negative binomial models adjusting for physicians' gender, specialty, and practice location. The adjusted absolute changes in outcomes were estimated by calculating the differences in predicted outcomes at each level of the interaction terms for each observation and averaging over the entire sample. P-value was adjusted for multiple comparisons using the Benjamini-Hochberg method.

Supplementary table D. Change in the number of industry payments per physician during the COVID-19 pandemic (i.e., April-December vs. January-February in 2020) compared to 2019 according to physicians' gender and specialty.

Physician characteristics	Difference-difference estimates (95% CI) of the number of industry payments per 100 physicians		
	Relative % change	Absolute change	p-for-interaction ^a
Gender			
Male	-47.3 (-47.7 to -46.9)	-49.7 (-50.5 to -48.8)	ref
Female	-47.9 (-48.5 to -47.2)	-31.5 (-32.3 to -30.6)	0.30
Specialty			
Primary Care			
Internal Medicine	-38 (-38.9 to -37.2)	-35.1 (-36.6 to -33.7)	ref
Family Medicine	-20.6 (-21.6 to -19.6)	-8.9 (-10.2 to -7.5)	<0.001
Pediatrics	-54.6 (-56.1 to -53.0)	-16.7 (-17.6 to -15.8)	<0.001
Hospitalist	-56.2 (-59.8 to -52.3)	-20.5 (-23.3 to -17.6)	<0.001
Surgery			
Obstetrics/Gynecology	-53.1 (-54.4 to -51.7)	-29.1 (-30.8 to -27.4)	<0.001
General	-66.0 (-67.2 to -64.8)	-48.5 (-50.8 to -46.2)	<0.001
Orthopedic	-62.8 (-64.0 to -61.5)	-60.6 (-63.8 to -57.4)	<0.001
Otolaryngology	-64.9 (-66.7 to -62.9)	-39.9 (-42.9 to -37.0)	<0.001
Urology	-56.6 (-58.1 to -55)	-82.1 (-87.1 to -77.0)	<0.001
Neurosurgery	-58.8 (-61.5 to -55.9)	-63.8 (-70.9 to -56.7)	<0.001
Plastic	-66.1 (-68.9 to -63.1)	-48.6 (-54.2 to -42.9)	<0.001
Thoracic/Vascular	-61.4 (-64.4 to -58.1)	-71.6 (-80.9 to -62.3)	<0.001
Colorectal	-66.2 (-70 to -61.9)	-57.4 (-69.3 to -45.4)	<0.001
Specialists			
Emergency Medicine	-46.3 (-48.8 to -43.8)	-11.9 (-13.3 to -10.5)	<0.001
Psychiatry	-57.6 (-59.0 to -56.2)	-59.2 (-62.5 to -55.9)	<0.001
Anesthesiology	-46.8 (-49.0 to -44.4)	-16.8 (-18.5 to -15.2)	<0.001
Radiology	-59.0 (-61.7 to -56.0)	-17.7 (-19.6 to -15.9)	<0.001
Cardiology	-51.5 (-52.5 to -50.4)	-106.2 (-111.1 to -101.4)	<0.001
Ophthalmology	-52.7 (-54.3 to -51.0)	-45.2 (-47.9 to -42.5)	<0.001
Pediatric Specialty	-63.3 (-66.2 to -60.1)	-20.1 (-22.6 to -17.5)	<0.001
Neurology	-51.1 (-52.6 to -49.5)	-147.3 (-156.4 to -138.1)	<0.001
Rehabilitation	-38.4 (-41.8 to -34.8)	-23.2 (-27.3 to -19.0)	0.95
Dermatology	-47.9 (-49.3 to -46.3)	-101.2 (-107.5 to -94.9)	<0.001
Gastroenterology	-57.1 (-58.4 to -55.8)	-112.1 (-117.5 to -106.7)	<0.001
Hematology/Oncology	-60.2 (-61.8 to -58.6)	-128.7 (-136.5 to -120.9)	<0.001
Nephrology	-63.7 (-65.6 to -61.6)	-71.9 (-77.4 to -66.4)	<0.001
Pulmonology	-39.5 (-41.7 to -37.1)	-56.1 (-64.1 to -48.0)	0.48
Infectious Diseases	-63.7 (-66.3 to -60.8)	-78.5 (-87.6 to -69.4)	<0.001
Endocrinology	-41.8 (-44.3 to -39.3)	-113.9 (-128.3 to -99.4)	<0.001
Rheumatology	-55.9 (-57.8 to -53.9)	-241.9 (-262 to -221.8)	<0.001
Allergy/Immunology	-24.6 (-27.9 to -21.2)	-21.5 (-32.1 to -10.8)	<0.001
Others	-44.1 (-46.8 to -41.3)	-17.8 (-19.6 to -16.1)	<0.001

^aP-value (adjusted for multiple comparisons using the Benjamini-Hochberg method) of the multiplicative 3-way interaction term between i) the year indicator (i.e., 2019 vs. 2020), ii) the month indicator (i.e., January-February vs. April-December), and iii) gender or specialty.

Supplementary table E. Change in value and number of industry payments per physician during the COVID-19 pandemic (i.e., January-February vs. April-December in 2020) compared to the average outcomes in 2018 and 2019 according to the type of payments.

Type of payments	Difference-in-difference estimates (95% CI) of the value of industry payments per physician			Difference-in-difference estimates (95% CI) of the number of industry payments per 100 physicians		
	Relative % change	Absolute \$ change	Adjusted p-value	Relative % change	Absolute change	Adjusted p-value
Total	-49.2 (-51.1 to -47.3)	-77.0 (-81.6 to -72.4)	<0.001	-47.9 (-48.2 to -47.6)	-44.6 (-45.1 to -44.0)	<0.001
Meal	-64.0 (-64.3 to -63.7)	-14.9 (-15.1 to -14.8)	<0.001	-46.5 (-46.8 to -46.2)	-37.8 (-38.3 to -37.4)	<0.001
Travel	-93.9 (-94.3 to -93.4)	-19.1 (-20.0 to -18.3)	<0.001	-91.3 (-91.8 to -90.9)	-5.8 (-6.0 to -5.6)	<0.001
Consulting	-18.3 (-25.0 to -11.1)	-8.0 (-11.3 to -4.6)	<0.001	+1.6 (-2.2 to +5.6)	±0.0 (±0.0 to +0.1)	0.50
Speaking fee	-36.9 (-41.1 to -32.4)	-13.3 (-15.4 to -11.3)	<0.001	-34.8 (-37.0 to -32.5)	-0.9 (-0.9 to -0.8)	<0.001
Honoraria	-51.8 (-57.8 to -44.9)	-2.5 (-3.0 to -2.0)	<0.001	-5.5 (-27.6 to +23.3)	±0.0 (±0.0 to ±0.0)	0.68
Others	-17.1 (-32.3 to +1.5)	-1.4 (-2.8 to ±0.0)	0.07	-34.6 (-36.9 to -32.2)	-0.3 (-0.4 to -0.2)	<0.001

Difference-in-difference estimates in relative percentage changes were calculated by regression coefficients of the interaction terms between the year indicator (i.e., 2018/2019 vs. 2020) and the month indicator (i.e., January-February vs. April-December) in the multivariable negative binomial models adjusting for physicians' gender, specialty, and practice location. The adjusted absolute changes in outcomes were estimated by calculating the differences in predicted outcomes at each level of the interaction terms for each observation and averaging over the entire sample. P-value was adjusted for multiple comparisons using the Benjamini-Hochberg method.

Supplementary table F. Change in value and number of industry payments per physician during the COVID-19 pandemic (i.e., January-February vs. April-December in 2020) compared to 2019 according to the type of payments using ordinary least squares regression models.

Type of payments	Difference-in-difference estimates (95% CI) of the value (\$) of industry payments per physician	Adjusted p-value	Difference-in-difference estimates (95% CI) of the number of industry payments per 100 physicians	Adjusted p-value
Total	-82.2 (-86.2 to -78.2)	<0.001	-41.7 (-42.3 to -41.1)	<0.001
Meal	-14.1 (-14.3 to -13.9)	<0.001	-34.9 (-35.4 to -34.4)	<0.001
Travel	-17.2 (-17.8 to -16.5)	<0.001	-5.9 (-6.0 to -5.7)	<0.001
Consulting	-6.9 (-9.6 to -4.2)	<0.001	+0.1 (±0.0 to +0.1)	0.02
Speaking fee	-39.6 (-41.7 to -37.4)	<0.001	-1.0 (-1.1 to -0.9)	<0.001
Honoraria	-2.3 (-2.9 to -1.8)	<0.001	±0.0 (-0.1 to +0.1)	0.83
Others	-2.2 (-3.1 to -1.2)	<0.001	-0.1 (-0.1 to ±0.0)	0.13

Difference-in-difference estimates in absolute changes were calculated by regression coefficients of the interaction terms between the year indicator (i.e., 2019 vs. 2020) and the month indicator (i.e., January-February vs. April-December) in the multivariable ordinary least squares regression models adjusting for physicians' gender, specialty, and practice location. P-value was adjusted for multiple comparisons using the Benjamini-Hochberg method.