

# **Behavioral Responses to Supply-Side Drug Policy During the Opioid Epidemic**

## **Appendix**

### **Appendix A Supplementary Material**

Table A.1: Descriptive statistics

	Mean	SD	Min	Max	N
<b>PDMP AND STATE CHARACTERISTICS</b>					
PDMP	0.34	0.48	0.00	1.00	1,326
Unemployment rate	5.47	1.86	2.30	13.70	1,326
Population	5,798,960	6,497,685	473,228	39,250,017	1,326
Income per capita	35,963	11,259	15,667	82,111	1,326
GDP per capita	49,135	18,550	29,599	183,971	1,326
<b>BCBS CLAIMS DATA: USERS AND PRESCRIPTIONS</b>					
Enrollees with opioid prescriptions	127,320	135,124	1,047	652,596	357
Enrollees with opioid prescriptions ex. 50 MME/day	65,438	70,453	534	325,001	357
Enrollees with opioid prescriptions ex. 90 MME/day	51,988	58,289	425	266,577	357
Opioid prescriptions	382,976	409,158	3,078	1,889,955	357
Opioid prescriptions ex. 50 MME/day	260,949	282,421	2,117	1,349,301	357
Opioid prescriptions ex. 90 MME/day	234,474	258,370	1,859	1,231,747	357
Dosage: Dosage prescribed in MME	307,472,169	348,057,139	3,371,442	1,738,444,647	357
Dosage: Days supply prescribed	6,199,656	6,864,123	46,783	31,921,827	357
Dosage: Prescriptions strength (MME/day)	18,982,779	22,334,110	182,547	198,875,074	357
Dosage: Per-claim dosage in MME prescribed	850	961	180	14,339	357
Dosage: Per-claim days supply prescribed	16	2	12	21	357
Dosage: Per-claim prescriptions strength	51	35	13	550	357
Prescriptions: Oxycodone	87,500	100,042	768	594,673	357
Prescriptions: Hydrocodone	176,684	205,253	1,457	1,163,905	357
Prescriptions: Oxymorphone	1,877	2,814	0	15,096	357
Prescriptions: Hydromorphone	4,906	5,317	18	28,852	357
Prescriptions: Morphine	9,641	10,858	99	59,514	357
Prescriptions: Fentanyl	6,752	8,203	48	55,663	357
Prescriptions: Codeine	23,068	39,205	175	369,885	357
Prescriptions: Tramadol	68,587	79,456	442	492,062	357
Prescriptions: Buprenorphine	14,992	17,980	82	97,733	357
Prescriptions: Methadone	3,091	3,519	38	18,093	357
Opioid-naïve patients: Enrollees w/ prescr.	37,803	42,674	212	267,346	357
Opioid-naïve patients: Enrollees w/ prescr. ex. 50 MME/day	11,605	13,370	72	90,386	357
Opioid-naïve patients: Dosage prescribed	7,664,671	9,377,116	43,171	83,495,436	357
Chronic users (ex. 90 days)	17,909	20,143	123	95,057	357
Chronic users (ex. 180 days)	11,633	12,971	82	60,150	357
Chronic users (ex. 360 days)	4,724	5,270	35	25,389	357
Chronic users: Dosage prescribed (ex. 90 days)	261,412,512	300,925,750	2,688,651	1,528,051,519	357
Chronic users: Dosage prescribed (ex. 180 days)	235,845,301	272,811,527	2,414,638	1,401,715,714	357
Chronic users: Dosage prescribed (ex. 360 days)	157,101,653	181,152,770	1,899,730	1,051,908,751	357
Chronic users: Per-claim dosage (ex. 90 days)	1,435	1,920	318	28,637	357
Chronic users: Per-claim dosage (ex. 180 days)	1,652	2,514	369	37,413	357
Chronic users: Per-claim dosage (ex. 360 days)	1,833	326	458	3,210	357
<b>ARCOS MANUFACTURER DRUG SHIPMENTS</b>					
Oxycodone/Hydrocodone manufacturer shipments	213,779,589	215,618,449	6,577,630	1,224,616,448	459
Oxycodone/Hydrocodone shipments to pharmacies	212,303,456	212,421,278	6,508,310	1,195,350,528	459
Oxycodone/Hydrocodone shipments to retail pharmacies	79,214,489	79,812,150	3,081,390	416,663,616	459
Oxycodone/Hydrocodone shipments to chain pharmacies	133,088,967	138,080,883	971,300	780,278,784	459
Oxycodone/Hydrocodone shipments to practitioners	1,476,132	4,819,428	13,080	41,312,796	459
<b>NSDUH DRUG USE SURVEY</b>					
Ever used pain relievers not prescribed by a doctor	542,205	655,162	24,000	5,062,000	459
Ever used heroin	85,802	105,608	2,000	741,000	510
Ever used sedatives or tranquilizers	491,525	604,663	11,000	4,104,000	408
Ever used benzodiazepines	393,503	425,150	11,000	2,657,000	306
Ever received treatment for drug use	28,155	29,574	1,000	195,000	459
<b>NVSS MORTALITY DATA</b>					
Mortality, all opioids	512	667	1	5,769	969
Mortality, semi-synthetic opioids	176	215	0	1,279	969
Mortality, heroin	107	192	0	1,491	969
Mortality, heroin and synthetic opioids	206	425	0	4,636	969
Mortality, methadone	72	83	0	608	969

Sources: Blue Cross Blue Shield Axis<sup>®</sup> database, DEA ARCOS data provided by the Washington Post, National Survey on Drug Use and Health, National Vital Statistics System.

Table A.2: PDMP Enactment and Operational Dates by State

State	(1) Legislative enactment	(2) Operational (user access)
Alabama	August 2004	April 2006
Alaska	September 2008	January 2012
Arizona	September 2007	December 2008
Arkansas	July 2011	May 2013
California	January 2005	September 2009
Colorado	June 2005	February 2008
Connecticut	October 2006	July 2008
Delaware	July 2010	August 2012
District of Columbia	February 2014	October 2016
Florida	December 2010	October 2011
Georgia	July 2011	May 2013
Hawaii	December 1996	February 2012
Idaho	April 2000	April 2008
Illinois	April 2000	December 2009
Indiana	July 2007	July 2007
Iowa	May 2006	March 2009
Kansas	July 2008	April 2011
Kentucky	July 1998	July 1999
Louisiana	July 2006	January 2009
Maine	January 2004	January 2005
Maryland	October 2011	December 2013
Massachusetts	December 1992	January 2011
Michigan	January 2002	January 2003
Minnesota	July 2007	April 2010
Mississippi	June 2006	July 2008
Missouri	July 2017	n/a
Montana	July 2011	October 2012
Nebraska	August 2011	January 2017
Nevada	January 1996	February 2011
New Hampshire	June 2012	October 2014
New Jersey	August 2009	January 2012
New Mexico	July 2004	August 2005
New York	October 2006	June 2013
North Carolina	January 2006	July 2007
North Dakota	April 2005	October 2008
Ohio	May 2005	October 2006
Oklahoma	January 1991	July 2006
Oregon	July 2009	September 2011
Pennsylvania	June 2015	August 2016
Rhode Island	August 1995	September 2012
South Carolina	June 2006	February 2008
South Dakota	March 2010	March 2012
Tennessee	January 2003	January 2010
Texas	September 1999	August 2012
Utah	July 1995	January 2006
Vermont	May 2006	January 2009
Virginia	September 2003	June 2006
Washington	July 2007	January 2012
West Virginia	June 1995	May 2013
Wisconsin	June 2010	June 2013
Wyoming	July 2003	July 2013

Note: The data are collected by the authors using the following sources: Prescription Drug Abuse Policy System, National Alliance for Model State Drug Laws, Prescription Drug Monitoring Program Training and Technical Assistance Center, states' statutes, and Horwitz et al. (2018).

Table A.3: Test for Endogenous PDMP Adoption: Prescriptions

	All opioid Enrollees			All opioid prescriptions		
$Y_{t-1}$	-0.035 (0.023)	-0.026 (0.027)	-0.016 (0.026)	-0.034 (0.023)	-0.023 (0.024)	-0.019 (0.024)
$Y_{t-2}$		-0.010 (0.018)	-0.028 (0.029)		-0.013 (0.017)	-0.025 (0.024)
$Y_{t-3}$			0.001 (0.034)			-0.001 (0.027)
F-test (p-value)	0.144	0.410	0.564	0.147	0.420	0.573
	MME $\geq$ 50 Enrollees			MME $\geq$ 50 prescriptions		
$Y_{t-1}$	-0.036 (0.024)	-0.025 (0.028)	-0.015 (0.027)	-0.035 (0.023)	-0.022 (0.023)	-0.019 (0.024)
$Y_{t-2}$		-0.012 (0.018)	-0.027 (0.028)		-0.014 (0.016)	-0.024 (0.022)
$Y_{t-3}$			-0.002 (0.031)			-0.004 (0.024)
F-test (p-value)	0.139	0.398	0.566	0.143	0.410	0.577
	MME $\geq$ 90 Enrollees			MME $\geq$ 90 prescriptions		
$Y_{t-1}$	-0.034 (0.023)	-0.021 (0.028)	-0.010 (0.029)	-0.034 (0.023)	-0.020 (0.023)	-0.017 (0.025)
$Y_{t-2}$		-0.012 (0.017)	-0.028 (0.028)		-0.015 (0.016)	-0.024 (0.022)
$Y_{t-3}$			-0.001 (0.030)			-0.003 (0.022)
F-test (p-value)	0.154	0.420	0.571	0.151	0.419	0.584
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Results from linear regression (OLS). Standard errors clustered at the state level are shown in parentheses below the coefficients. The dependent variable is  $PDMP_{it}$  in all regressions.

Table A.4: Test for Endogenous PDMP Adoption: Dosage

	Total amount of MME			Total amount of days supply		
$Y_{t-1}$	-0.027 (0.020)	-0.012 (0.020)	-0.003 (0.032)	-0.037 (0.025)	-0.021 (0.023)	-0.019 (0.026)
$Y_{t-2}$		-0.018 (0.016)	-0.025 (0.023)		-0.017 (0.016)	-0.025 (0.023)
$Y_{t-3}$			-0.007 (0.023)			-0.005 (0.022)
F-test (p-value)	0.177	0.442	0.604	0.151	0.415	0.591
	Total amount of MME/day			Per-claim average MME		
$Y_{t-1}$	-0.027 (0.019)	-0.019 (0.023)	-0.014 (0.031)	0.013 (0.014)	0.017 (0.014)	0.009 (0.023)
$Y_{t-2}$		-0.012 (0.017)	-0.025 (0.024)		-0.007 (0.008)	-0.001 (0.006)
$Y_{t-3}$			-0.002 (0.026)			-0.007 (0.026)
F-test (p-value)	0.171	0.456	0.582	0.360	0.354	0.594
	Per-claim average days supply			Per-claim average MME/day		
$Y_{t-1}$	0.073 (0.573)	0.556 (0.418)	0.172 (0.353)	0.016 (0.019)	0.013 (0.018)	0.015 (0.029)
$Y_{t-2}$		-0.573 (0.991)	0.480 (0.581)		0.001 (0.015)	-0.003 (0.011)
$Y_{t-3}$			-0.740 (1.298)			0.009 (0.035)
F-test (p-value)	0.899	0.325	0.552	0.401	0.760	0.950
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Results from linear regression (OLS). Standard errors clustered at the state level are shown in parentheses below the coefficients. The dependent variable is  $PDMP_{it}$  in all regressions.

Table A.5: Test for Endogenous PDMP Adoption: Shipments

	Total Shipments			Shipments to pharmacies			Shipments to practitioners		
$Y_{t-1}$	-0.821 (0.383)	-0.626 (0.461)	-0.983 (0.538)	-0.834 (0.391)	-0.604 (0.476)	-0.963 (0.561)	0.025 (0.062)	-0.002 (0.071)	0.035 (0.083)
$Y_{t-2}$		-0.457 (0.576)	0.096 (0.533)		-0.524 (0.572)	0.008 (0.510)		0.025 (0.067)	0.054 (0.057)
$Y_{t-3}$			-0.079 (0.711)			-0.081 (0.713)			-0.020 (0.073)
F-test (p-value)	0.037	0.109	0.263	0.038	0.109	0.276	0.685	0.927	0.694
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Results from linear regression (OLS). Standard errors clustered at the state level are shown in parentheses below the coefficients. The dependent variable is  $PDMP_{it}$  in all regressions.

Table A.6: Test for Endogenous PDMP Adoption: Abuse

	Ever used pain relievers non-medically		Ever used heroin		Ever used sedatives or tranquilizers non-medically	
$Y_{t-1}$	-0.137 (0.270)	-0.166 (0.301)	-0.066 (0.077)	-0.135 (0.094)	-0.134 (0.215)	-0.190 (0.260)
$Y_{t-2}$		0.251 (0.328)		-0.063 (0.083)		0.046 (0.255)
F-test (p-value)	0.614	0.462	0.400	0.329	0.534	0.701
	Ever used benzodiazepines		Received treatment for illicit drug use			
$Y_{t-1}$	-0.060 (0.219)	-0.004 (0.260)	-0.013 (0.049)	-0.017 (0.071)		
$Y_{t-2}$		0.098 (0.213)		0.054 (0.084)		
F-test (p-value)	0.784	0.860	0.798	0.685		
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Results from linear regression (OLS). Standard errors clustered at the state level are shown in parentheses below the coefficients. The dependent variable is  $PDMP_{it}$  in all regressions.

Table A.7: Test for Endogenous PDMP Adoption: Mortality

	All opioids (ICD-9/10)			Opioid dependence (ICD-9/10)		
$Y_{t-1}$	0.006 (0.024)	-0.003 (0.019)	-0.008 (0.024)	-0.002 (0.017)	-0.005 (0.013)	-0.008 (0.013)
$Y_{t-2}$		0.013 (0.018)	0.016 (0.017)		0.005 (0.013)	0.003 (0.011)
$Y_{t-3}$			-0.001 (0.025)			0.006 (0.013)
F-test (p-value)	0.788	0.742	0.676	0.925	0.733	0.841
	All opioids (ICD-10)			Semi-synthetic opioids (ICD-10)		
$Y_{t-1}$	-0.008 (0.046)	-0.021 (0.038)	-0.019 (0.043)	-0.029 (0.030)	-0.022 (0.028)	-0.023 (0.031)
$Y_{t-2}$		0.020 (0.032)	0.023 (0.032)		0.004 (0.021)	0.028 (0.026)
$Y_{t-3}$			-0.003 (0.047)			-0.018 (0.032)
F-test (p-value)	0.860	0.540	0.655	0.335	0.544	0.066
	Heroin (ICD-10)			Heroin plus synthetic (ICD-10)		
$Y_{t-1}$	-0.020 (0.026)	-0.011 (0.019)	-0.008 (0.022)	-0.025 (0.026)	-0.029 (0.023)	-0.020 (0.025)
$Y_{t-2}$		-0.017 (0.017)	-0.011 (0.015)		0.001 (0.019)	-0.012 (0.022)
$Y_{t-3}$			-0.016 (0.021)			0.004 (0.028)
F-test (p-value)	0.437	0.617	0.730	0.336	0.419	0.855
	Methadone (ICD-10)					
$Y_{t-1}$	-0.051 (0.032)	-0.039 (0.027)	-0.037 (0.030)			
$Y_{t-2}$		-0.019 (0.024)	-0.003 (0.022)			
$Y_{t-3}$			-0.025 (0.027)			
F-test (p-value)	0.117	0.378	0.275			
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Results from linear regression (OLS). Standard errors clustered at the state level are shown in parentheses below the coefficients. The dependent variable is  $PDMP_{it}$  in all regressions.

Table A.8: Test for Endogenous PDMP Adoption: Hospitalizations (Drug Poisonings)

	All opioids			Opioid medication		
$Y_{t-1}$	-0.001 (0.002)	0.003 (0.003)	0.003 (0.002)	-0.001 (0.003)	0.005 (0.004)	0.004 (0.003)
$Y_{t-2}$		-0.001 (0.003)	-0.001 (0.003)		-0.001 (0.004)	-0.001 (0.004)
$Y_{t-3}$			-0.002 (0.003)			0.001 (0.004)
F-test (p-value)	0.954	0.536	0.337	0.895	0.497	0.429
	Heroin			Other/unspecified		
$Y_{t-1}$	0.001 (0.002)	0.002 (0.002)	0.001 (0.003)	0.002 (0.009)	0.006 (0.016)	0.001 (0.014)
$Y_{t-2}$		0.003 (0.003)	0.002 (0.004)		0.006 (0.012)	0.002 (0.017)
$Y_{t-3}$			-0.001 (0.003)			-0.006 (0.012)
F-test (p-value)	0.936	0.332	0.888	0.845	0.830	0.916
	Share heroin					
$Y_{t-1}$	0.001 (0.001)	0.001 (0.001)	-0.001 (0.001)			
$Y_{t-2}$		0.001 (0.001)	-0.001 (0.001)			
$Y_{t-3}$			-0.001 (0.001)			
F-test (p-value)	0.465	0.815	0.677			
Hospital FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Results from linear regression (OLS). Standard errors clustered at the hospital level are shown in parentheses below the coefficients. The dependent variable is  $PDMP_{it}$  in all regressions.

Table A.9: The Effect of Prescription Drug Monitoring Programs on Prescriptions by Opioid Medication

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Oxycodone	Hydrocodone	Oxymorphone	Hydromorphone	Morphine	Fentanyl	Codeine	Tramadol	Buprenorphine	Methadone
PDMP	-0.155 (0.034) [0.000]	-0.217 (0.056) [0.000]	0.006 (0.047) [0.891]	-0.138 (0.041) [0.001]	-0.101 (0.037) [0.006]	-0.123 (0.033) [0.000]	-0.116 (0.076) [0.129]	-0.081 (0.036) [0.023]	-0.117 (0.030) [0.000]	-0.077 (0.034) [0.023]
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
States	51	51	51	51	51	51	51	51	51	51
Observations	306	306	306	306	306	306	306	306	306	306

Note: Results from Poisson regression. Standard errors clustered at the state level are shown in parentheses below the coefficients. P-values are shown in square parentheses below the coefficients. Covariates include state census population (on a logarithmic scale), state unemployment rate, state per-capita personal income, state per-capita GDP, and lagged number of BCBS enrollees in the state (on a logarithmic scale). Data are from the Blue Cross Blue Shield Axis<sup>®</sup> database.

Table A.10: The Effect of Prescription Drug Monitoring Programs on Opioid Prescriptions, Callaway/Sant’ Anna ATT-Estimator

	(1)	(2)	(3)	(4)	(5)	(6)
(A) PRESCRIPTIONS						
	All opioid prescriptions		High dosage (MME/day $\geq$ 50)		Very high dosage (MME/day $\geq$ 90)	
	Enrollees	Prescriptions	Enrollees	Prescriptions	Enrollees	Prescriptions
Early PDMP adopters	-0.364 (0.096) [0.000]	-0.351 (0.102) [0.001]	-0.357 (0.088) [0.000]	-0.329 (0.099) [0.001]	-0.350 (0.085) [0.000]	-0.321 (0.100) [0.001]
Intermediate PDMP adopters	-0.142 (0.064) [0.029]	-0.136 (0.062) [0.028]	-0.142 (0.060) [0.019]	-0.134 (0.057) [0.020]	-0.123 (0.060) [0.043]	-0.127 (0.057) [0.026]
Late PDMP adopters	-0.020 (0.010) [0.043]	-0.029 (0.012) [0.012]	0.007 (0.019) [0.688]	-0.028 (0.017) [0.096]	0.048 (0.018) [0.009]	-0.009 (0.016) [0.546]
(B) DOSAGE						
	Total amount			Per-claim average		
	Dosage in MME	Duration in days	Strength in MME/day	Dosage in MME	Duration in days	Strength in MME/day
Early PDMP adopters	-0.289 (0.097) [0.003]	-0.323 (0.096) [0.001]	-0.289 (0.098) [0.004]	0.062 (0.047) [0.182]	0.028 (0.006) [0.000]	0.062 (0.033) [0.064]
Intermediate PDMP adopters	-0.036 (0.063) [0.573]	-0.121 (0.059) [0.042]	-0.080 (0.057) [0.162]	0.101 (0.088) [0.255]	0.016 (0.011) [0.152]	0.056 (0.069) [0.417]
Late PDMP adopters	-0.017 (0.016) [0.275]	-0.007 (0.014) [0.599]	-0.020 (0.016) [0.231]	0.012 (0.007) [0.067]	0.022 (0.004) [0.000]	0.010 (0.018) [0.580]
States	51	51	51	51	51	51
Observations	306	306	306	306	306	306

Note: Results are obtained using the estimator by Callaway and Sant’ Anna (2020). All regressions include state fixed effects and time fixed effects. Standard errors clustered at the state level are shown in parentheses below the coefficients, whereas p-values are shown in square parentheses below the coefficients. Data are from the Blue Cross Blue Shield Axis<sup>®</sup> database.

Table A.11: The Effect of Prescription Drug Monitoring Programs on Opioid Prescriptions, Callaway/Sant’ Anna ATT-Estimator

	(1)	(2)	(3)	(4)	(5)	(6)
(A) PRESCRIPTIONS						
	All opioid prescriptions		High dosage (MME/day $\geq$ 50)		Very high dosage (MME/day $\geq$ 90)	
	Enrollees	Prescriptions	Enrollees	Prescriptions	Enrollees	Prescriptions
PDMP	-0.167 (0.045) [0.000]	-0.163 (0.049) [0.001]	-0.158 (0.042) [0.000]	-0.157 (0.043) [0.000]	-0.137 (0.047) [0.004]	-0.146 (0.044) [0.001]
(B) DOSAGE						
	Total amount			Per-claim average		
	Dosage in MME	Duration in days	Strength in MME/day	Dosage in MME	Duration in days	Strength in MME/day
PDMP	-0.094 (0.049) [0.058]	-0.143 (0.043) [0.001]	-0.117 (0.042) [0.005]	0.069 (0.057) [0.225]	0.020 (0.007) [0.003]	0.046 (0.044) [0.302]
Covariates	No	No	No	No	No	No
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
States	51	51	51	51	51	51
Observations	306	306	306	306	306	306

Note: Results are obtained using the estimator by Callaway and Sant’ Anna (2020). Standard errors clustered at the state level are shown in parentheses below the coefficients, whereas p-values are shown in square parentheses below the coefficients. Data are from the Blue Cross Blue Shield Axis<sup>®</sup> database.

Table A.12: Heterogeneity Analysis for Hospital Admissions

	(1) Opioid medication	(2) Heroin
PDMP effect for men	-0.097 (0.016) [0.000]	0.080 (0.029) [0.006]
PDMP effect for women	-0.041 (0.016) [0.009]	0.066 (0.043) [0.126]
PDMP effect for white	-0.070 (0.021) [0.001]	0.370 (0.041) [0.000]
PDMP effect for non-white	-0.011 (0.031) [0.729]	0.091 (0.062) [0.138]
Covariates	Yes	Yes
Hospital FE	Yes	Yes
Time FE	Yes	Yes
Hospitals	2,973	2,973
Observations	16,369	16,369

Note: Results from Poisson regression. Standard errors clustered at the hospital level are shown in parentheses below the coefficients. P-values are shown in square parentheses below the coefficients. Covariates include hospital size (on a logarithmic scale), state census population (on a logarithmic scale), state unemployment rate, state per-capita personal income, and state per-capita GDP. Data are from the National Inpatient Sample (NIS).

Table A.13: Controlling for state-level policies: The Effect of Prescription Drug Monitoring Programs on Opioid Prescriptions

(A) USERS						
	All opioid prescriptions		High dosage (MME/day $\geq$ 50)		Very high dosage (MME/day $\geq$ 90)	
PDMP	-0.126 (0.037) [0.001]	-0.135 (0.044) [0.002]	-0.122 (0.038) [0.001]	-0.127 (0.046) [0.005]	-0.108 (0.042) [0.010]	-0.106 (0.049) [0.031]
(B) RX						
	All opioid prescriptions		High dosage (MME/day $\geq$ 50)		Very high dosage (MME/day $\geq$ 90)	
PDMP	-0.126 (0.034) [0.000]	-0.131 (0.040) [0.001]	-0.112 (0.033) [0.001]	-0.115 (0.039) [0.001]	-0.109 (0.035) [0.003]	-0.107 (0.040) [0.008]
State prescription drug policies	Yes	Yes	Yes	Yes	Yes	Yes
State marijuana disp. policies		Yes		Yes		Yes
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
States	51	51	51	51	51	51
Observations	306	306	306	306	306	306

Note: Results from Poisson regression. Standard errors clustered at the state level are shown in parentheses below the coefficients. P-values are shown in square parentheses below the coefficients. Covariates include state census population (on a logarithmic scale), state unemployment rate, state per-capita personal income, state per-capita GDP, and lagged number of BCBS enrollees in the state (on a logarithmic scale). Other state prescription drug policies policies included are prescription duration limits, pill mill regulation, naloxone access and good samaritan laws. Marijuana policies measure access to medical and recreational marijuana through dispensaries. Prescription data are from the Blue Cross Blue Shield Axis<sup>®</sup> database.

Table A.14: Controlling for State-Level Policies: The Effect of Prescription Drug Monitoring Programs on Opioid Consumption

RESPONDENTS DRUG USE BY SUBSTANCE										
	Ever used pain relievers w/o prescription		Ever used heroin		Ever used sedatives or tranquilizers w/o prescription		Ever used benzodiazepines		Received treatment for illicit drug use	
PDMP	0.029 (0.014) [0.034]	0.030 (0.013) [0.020]	0.086 (0.052) [0.098]	0.086 (0.052) [0.097]	0.046 (0.022) [0.033]	0.048 (0.021) [0.020]	0.053 (0.023) [0.019]	0.054 (0.022) [0.015]	-0.059 (0.048) [0.221]	-0.065 (0.049) [0.179]
State prescription drug policies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State marijuana disp. policies		Yes		Yes		Yes		Yes		Yes
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
States	51	51	51	51	51	51	51	51	51	51
Observations	306	306	357	357	306	306	306	306	306	306

Note: Results from Poisson regression. Standard errors clustered at the state level are shown in parentheses below the coefficients. P-values are shown in square parentheses below the coefficients. Covariates include state census population (on a logarithmic scale), state unemployment rate, state per-capita personal income, and state per-capita GDP. Other state prescription drug policies policies included are prescription duration limits, pill mill regulation, naloxone access and good samaritan laws. Marijuana policies measure access to medical and recreational marijuana through dispensaries. Drug use data are from the National Survey on Drug Use and Health (NSDUH). The sample size differs for heroin compared to the other outcomes due to data availability for one additional survey year.

Table A.15: Controlling for State-Level Policies: The effect of Prescription Drug Monitoring Programs on Mortality

	MORTALITY BY CAUSE OF DEATH 1999-2017 (ICD-10)											
	All opioids		Semi-synthetic opioids		Heroin		Heroin or synthetic		Methadone		Share heroin	
PDMP	-0.006 (0.056) [0.820]	0.007 (0.056) [0.772]	-0.084 (0.047) [0.000]	-0.068 (0.047) [0.003]	0.076 (0.094) [0.074]	0.085 (0.090) [0.049]	0.103 (0.074) [0.008]	0.110 (0.072) [0.002]	-0.012 (0.052) [0.541]	-0.011 (0.052) [0.559]	0.071 (0.131) [0.069]	0.076 (0.129) [0.052]
State prescription drug policies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State marijuana disp. policies		Yes		Yes		Yes		Yes		Yes		Yes
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
States	51	51	51	51	51	51	51	51	51	51	51	51
Observations	969	969	969	969	969	969	969	969	969	969	969	969

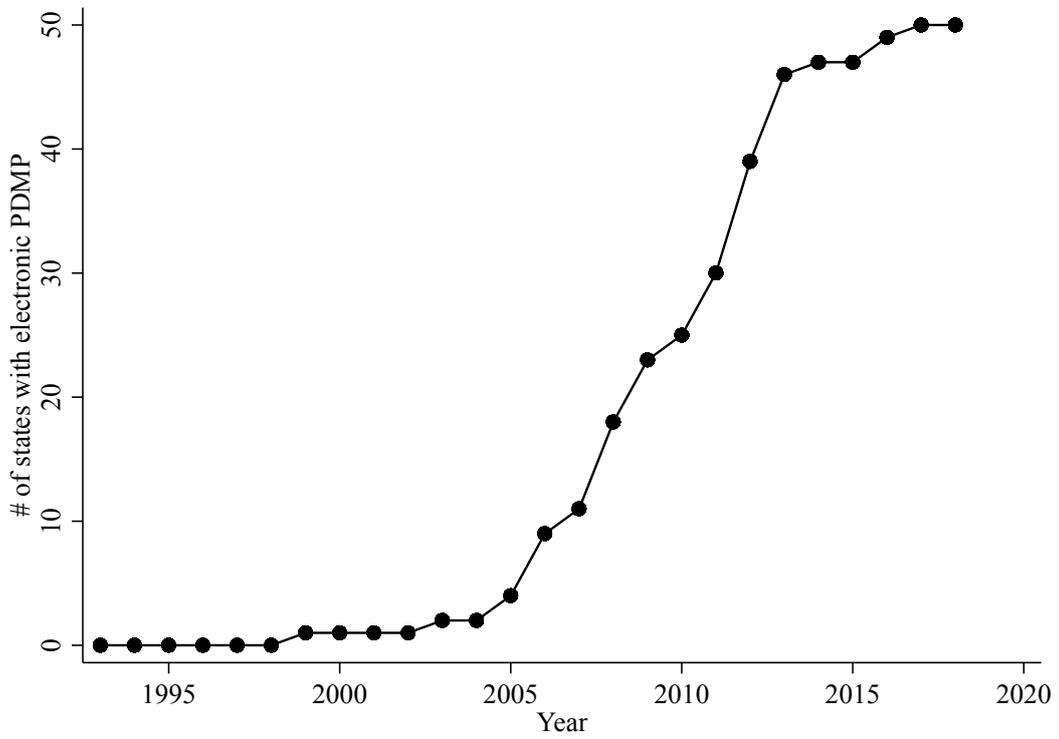
Note: Results from Poisson regression. Standard errors clustered at the state level are shown in parentheses below the coefficients. Randomization inference p-values are shown in square parentheses below the coefficients (1,000 resampling replications). Covariates include state census population (on a logarithmic scale), state unemployment rate, state per-capita personal income, and state per-capita GDP. Other state prescription drug policies policies included are prescription duration limits, pill mill regulation, naloxone access and good samaritan laws. Marijuana policies measure access to medical and recreational marijuana through dispensaries. Mortality data are from the National Vital Statistics System (NVSS).

Table A.16: Controlling for State-Level Policies: The effect of Prescription Drug Monitoring Programs on Hospitalizations

	All opioids		Opioid medication		Heroin		Other/unspecified		Share heroin	
PDMP	-0.002 (0.012) [0.889]	-0.002 (0.012) [0.866]	-0.062 (0.013) [0.000]	-0.056 (0.013) [0.000]	0.131 (0.028) [0.000]	0.146 (0.028) [0.000]	0.038 (0.025) [0.133]	0.030 (0.025) [0.239]	0.183 (0.043) [0.000]	0.178 (0.043) [0.000]
State prescription drug policies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State marijuana disp. policies		Yes		Yes		Yes		Yes		Yes
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hospital FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hospitals	2,973	2,973	2,973	2,973	2,973	2,973	2,973	2,973	2,973	2,973
Observations	16,369	16,369	16,369	16,369	16,369	16,369	16,369	16,369	16,369	16,369

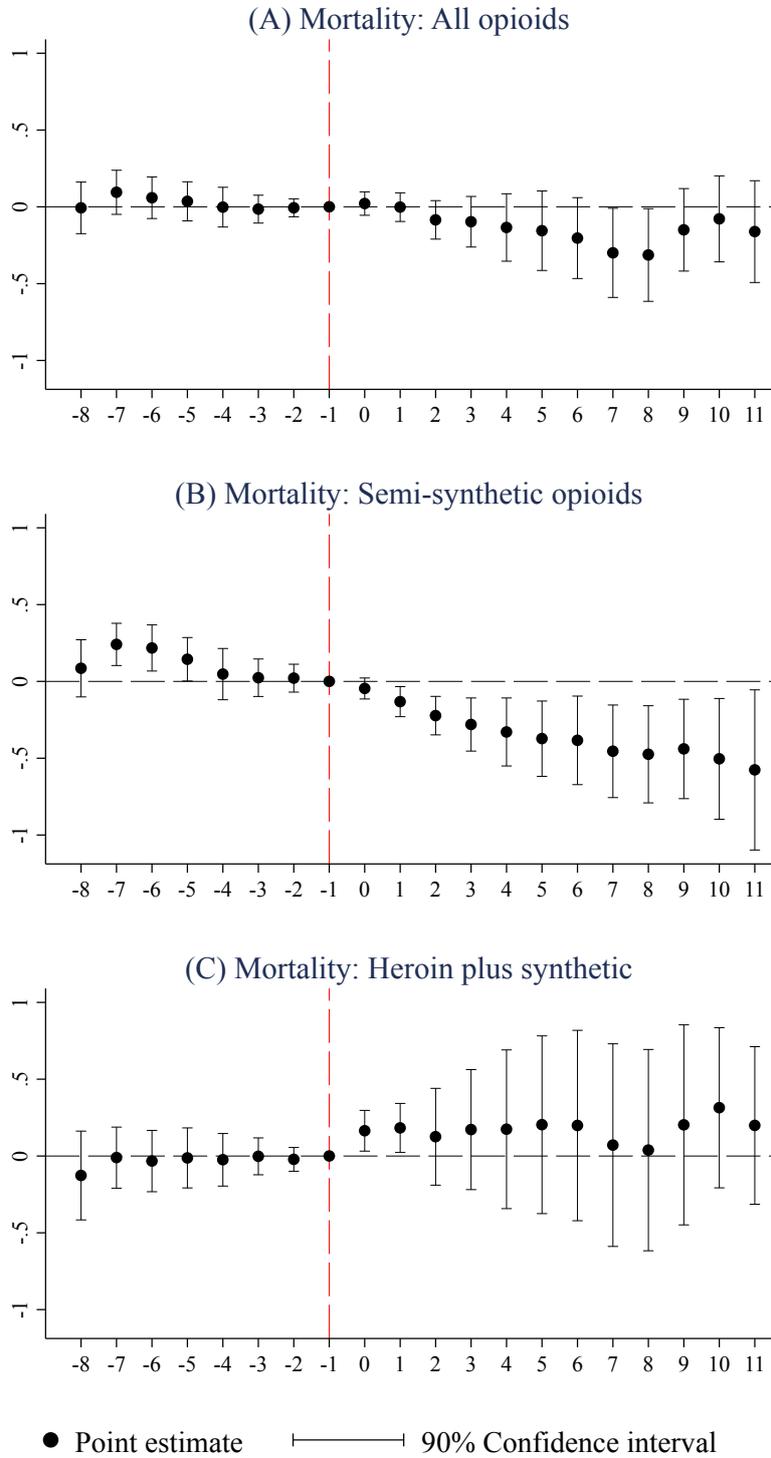
Note: Results from Poisson regression. Standard errors clustered at the hospital level are shown in parentheses below the coefficients. P-values are shown in square parentheses below the coefficients. Covariates include hospital size (on a logarithmic scale), state census population (on a logarithmic scale), state unemployment rate, state per-capita personal income, and state per-capita GDP. Other state prescription drug policies policies included are prescription duration limits, pill mill regulation, naloxone access and good samaritan laws. Marijuana policies measure access to medical and recreational marijuana through dispensaries. Hospitalization data are from the National Inpatient Sample (NIS).

Figure A.1: Staggered Implementation of PDMPs Over Time



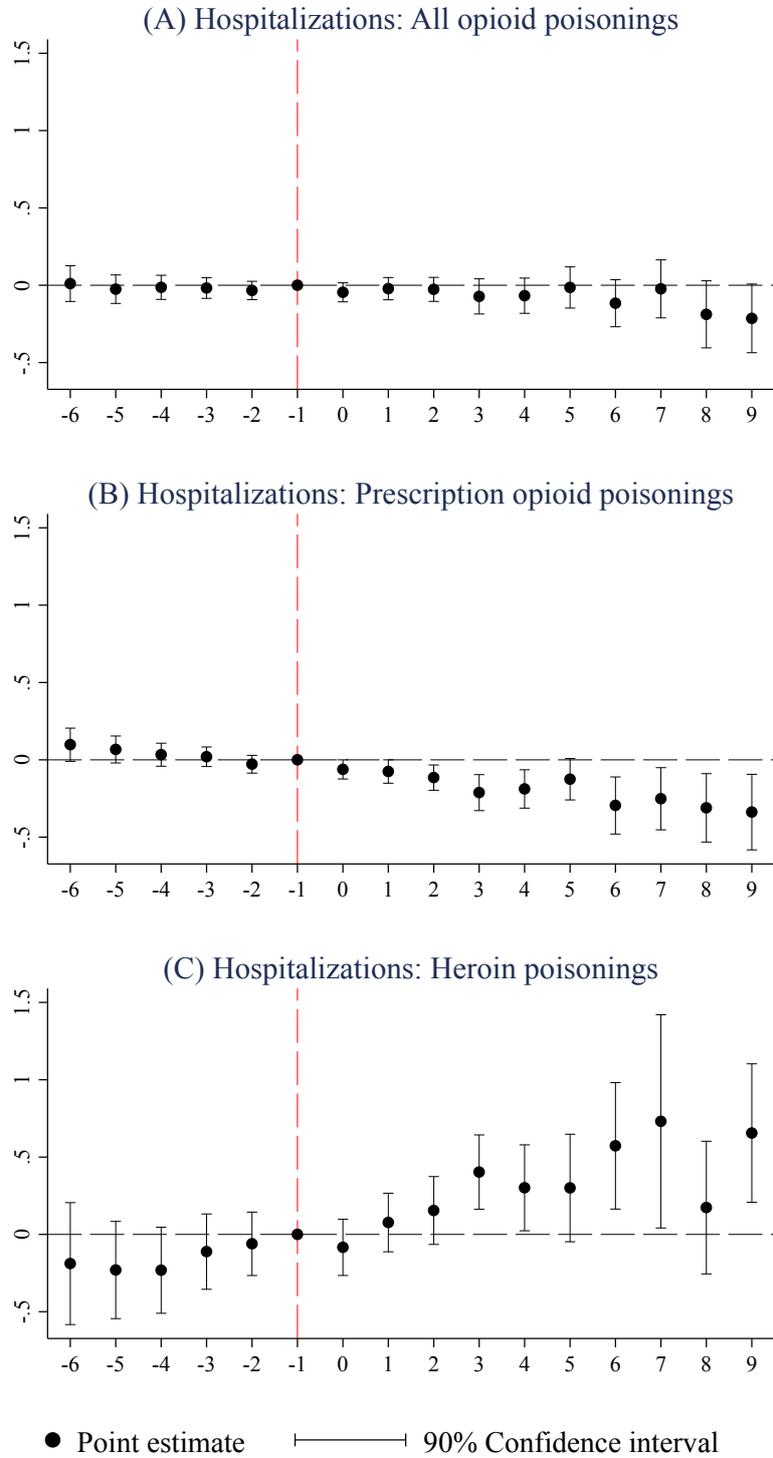
Note: The data are collected by the authors using the following sources: Prescription Drug Abuse Policy System, National Alliance for Model State Drug Laws, Prescription Drug Monitoring Program Training and Technical Assistance Center, states' statutes, and Horowitz et al. (2018).

Figure A.2: Event study analysis: Mortality



Note: Results from Poisson regression, with standard errors clustered at the state level. Data are from the National Vital Statistics System (NVSS).

Figure A.3: Event study analysis: Hospitalizations



Note: Results from Poisson regression, with standard errors clustered at the hospital level. Data are from the National Inpatient Sample (NIS).

## **Appendix B Linear Model Results**

Table B.1: The Effect of Prescription Drug Monitoring Programs on Opioid Prescriptions, Linear Models

	(1)	(2)	(3)	(4)	(5)	(6)
(A) PRESCRIPTIONS						
	All opioid prescriptions		High dosage (MME/day $\geq$ 50)		Very high dosage (MME/day $\geq$ 90)	
	Enrollees	Prescriptions	Enrollees	Prescriptions	Enrollees	Prescriptions
PDMP	-0.098 (0.071) [0.032]	-0.105 (0.070) [0.029]	-0.105 (0.078) [0.023]	-0.106 (0.071) [0.035]	-0.075 (0.087) [0.093]	-0.095 (0.076) [0.051]
(B) DOSAGE						
	Total amount			Per-claim average		
	Dosage in MME	Duration in days	Strength in MME/day	Dosage in MME	Duration in days	Strength in MME/day
PDMP	-0.140 (0.090) [0.037]	-0.097 (0.074) [0.041]	-0.139 (0.083) [0.024]	-0.035 (0.053) [0.474]	0.008 (0.010) [0.139]	-0.033 (0.049) [0.444]
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
States	51	51	51	51	51	51
Observations	306	306	306	306	306	306

Note: Results from linear regression (OLS). Standard errors clustered at the state level are shown in parentheses below the coefficients. Randomization inference p-values are shown in square parentheses below the coefficients (1,000 resampling replications). Covariates include state census population (on a logarithmic scale), state unemployment rate, state per-capita personal income, state per-capita GDP, and lagged number of BCBS enrollees in the state (on a logarithmic scale). Data are from the Blue Cross Blue Shield Axis<sup>®</sup> database.

Table B.2: The Effect of Prescription Drug Monitoring Programs on Drug Shipments (Oxycodone/Hydrocodone), Linear Models

	(1) Total shipments	(2) Shipments to pharmacies	(3) Shipments to retail pharmacies	(4) Shipments to chain pharmacies	(5) Shipments to practitioners
PDMP	-0.030 (0.018) [0.000]	-0.029 (0.018) [0.000]	-0.044 (0.028) [0.000]	-0.023 (0.019) [0.002]	-0.091 (0.127) [0.033]
Covariates	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
States	51	51	51	51	51
Observations	459	459	459	459	459

Note: Results from linear regression (OLS). Standard errors clustered at the state level are shown in parentheses below the coefficients. Randomization inference p-values are shown in square parentheses below the coefficients (1,000 resampling replications). Covariates include state census population (on a logarithmic scale), state unemployment rate, state per-capita personal income, and state per-capita GDP. Shipments are based on the DEA's Automation of Reports and Consolidates Orders System data, accessed using the Washington Post's ARCOS API (<https://github.com/wpinvestigative/arcos-api>).

Table B.3: The Effect of Prescription Drug Monitoring Programs on Opioid Consumption, Linear Models

	(1)	(2)	(3)	(4)	(5)
	Ever used pain relievers non-medically	Ever used heroin	Ever used sedatives or tranquilizers non-medically	Ever used benzodiazepines	Received treatment for illicit drug use
PDMP	0.021 (0.023) [0.359]	0.092 (0.051) [0.080]	0.034 (0.033) [0.298]	0.042 (0.035) [0.235]	-0.031 (0.091) [0.733]
Covariates	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
States	51	51	51	51	51
Observations	306	357	306	306	306

Note: Results from linear regression (OLS). Standard errors clustered at the state level are shown in parentheses below the coefficients. P-values are shown in square parentheses below the coefficients. Covariates include state census population (on a logarithmic scale), state unemployment rate, state per-capita personal income, and state per-capita GDP. Data are from the National Survey on Drug Use and Health (NSDUH).

Table B.4: The effect of Prescription Drug Monitoring Programs on Mortality, Linear Models

	1993-2017 (ICD-9 and ICD-10)		1999-2017 (ICD-10)			
	(1) All opioids	(2) Opioid dependence	(3) All opioids	(4) Semi-synthetic opioids	(5) Heroin	(6) Methadone
PDMP	0.008 (0.086) [0.797]	-0.034 (0.165) [0.467]	-0.021 (0.069) [0.410]	-0.090 (0.062) [0.002]	0.131 (0.207) [0.010]	-0.162 (0.092) [0.000]
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
States	51	51	51	51	51	51
Observations	1,275	1,275	969	969	969	969

Note: Results from linear regression (OLS). Standard errors clustered at the state level are shown in parentheses below the coefficients. Randomization inference p-values are shown in square parentheses below the coefficients (1,000 resampling replications). Covariates include state census population (on a logarithmic scale), state unemployment rate, state per-capita personal income, and state per-capita GDP. Data are from the National Vital Statistics System (NVSS).

Table B.5: The effect of Prescription Drug Monitoring Programs on Hospitalizations, Linear Models

	(1) All opioids	(2) Opioid medication	(3) Heroin	(4) Other/unspecified	(5) Share heroin
PDMP	-0.005 (0.033) [0.877]	-0.061 (0.036) [0.085]	0.110 (0.048) [0.021]	0.041 (0.054) [0.443]	1.305 (0.457) [0.004]
Covariates	Yes	Yes	Yes	Yes	Yes
Hospital FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Hospitals	2,973	2,973	2,973	2,973	2,973
Observations	16,369	16,369	16,369	16,369	16,369

Note: Results from linear regression (OLS). Standard errors clustered at the hospital level are shown in parentheses below the coefficients. P-values are shown in square parentheses below the coefficients. Covariates include hospital size (on a logarithmic scale), state census population (on a logarithmic scale), state unemployment rate, state per-capita personal income, and state per-capita GDP. Data are from the National Inpatient Sample (NIS).