

Appendix

Drug overdose deaths

Mortality files were generated at NCHS by extracting information recorded from death certificates filed in the 50 states and the District of Columbia. Deaths were classified by NCHS using the International Classification of Diseases, Tenth Revision (ICD–10). Drug overdose deaths were defined as having an ICD–10 underlying cause-of-death code of X40–X44, X60–X64, X85, or Y10–Y14. Drugs involved were determined using ICD–10 multiple cause-of-death codes of T40.1 for heroin, T40.2, T40.3, or T40.4 for prescription opioids, T40.6 for unspecified narcotics, and T50.9 for unspecified drug(s).

Variation in the reporting of drug-specific information on death certificates across states affects state-level drug-specific death rates. In addition, NCHS suggests that if an underlying cause has less than twenty deaths in a state, it should not be used for calculating death rate for analysis due to potential unreliability. (National Center for Health Statistics. Compressed Mortality File, 1999–2011, CD-ROM Series 20, No. 2Q. July 28, 2014. http://www.cdc.gov/nchs/data/mortab/1999-2011CMFDocumentation_8_5_14.pdf, Accessed October 30, 2015.) To address this and the concern that any potential changes in these reporting practices could coincide with policies resulting from increased attention to opioids, we 1) created “combined” drug overdose deaths per 100,000 residents as an outcome, combining heroin, prescription opioids, unspecified narcotics (which could involve either prescription opioids or heroin or both), and unspecified drug related deaths. This captured all drug overdose deaths that were either reported as related to heroin or prescription opioids or that could potentially have involved heroin or prescription opioids if more drug-specific information had been included on the death certificate; 2) included totals of unspecified narcotics and unspecified drug-related deaths as a covariate when heroin and prescription opioids related deaths were outcomes in regressions; 3) included pending deaths as a covariate when heroin, prescription opioids, and combined drug overdose deaths were outcomes in regressions.

Opioid prescribing

We identified opioid prescriptions, including hydrocodone, oxycodone, fentanyl, oxymorphone, hydromorphone, methadone, morphine, propoxyphene, tapentadol, codeine, and tramadol using the National Drug Code (NDC). We did not include cough and cold formulations containing opioids and did not include buprenorphine, an opioid partial agonist used for treatment of opioid use disorder as well as for pain. In addition, methadone dispensed through methadone maintenance treatment programs is not included in IMS data. To obtain milligrams of opioids prescribed in morphine equivalents (MME) per state resident per year, we multiplied milligrams of opioids prescribed annually by an MME conversion factor for each drug (available at See National Center for Injury Prevention and Control. CDC compilation of opioid analgesic formulations with morphine milligram equivalent conversion factors, 2015 version. Atlanta, GA: Centers for Disease Control and Prevention; 2015. http://www.pdmpassist.org/pdf/BJA_performance_measure_aid_MME_conversion.pdf. Accessed October 30, 2015). We then summed MMEs for all opioid drugs and divided total MMEs prescribed annually by number of state residents.

Estimates for state-level per-population buprenorphine treatment capacity

We estimated state-level buprenorphine treatment capacity using Substance Abuse and Mental Health Service Administration (SAMHSA) data on physicians who were eligible to provide buprenorphine for opioid use disorder for 30 patients or for 100 patients. See “Number of DATA-Certified Physicians” at <http://www.samhsa.gov/medication-assisted-treatment/physician-program-data/certified-physicians> (accessed May 29, 2016). Capacity was estimated as number of patients that could be treated if all physicians treated the maximum number of patients they were eligible to treat.

Estimated buprenorphine treatment capacity per 10,000 population

	2006	2007	2008	2009	2010	2011	2012	2013
Kentucky	0.79	6.59	4.97	7.30	5.13	6.16	11.32	13.46
Ohio	1.12	6.46	3.34	3.43	4.63	3.50	6.06	8.81
Tennessee	1.00	7.56	4.08	4.68	6.32	5.08	5.02	6.65
West Virginia	0.33	8.49	7.55	9.95	7.33	8.69	8.37	11.82

pain clinic law only states

	2006	2007	2008	2009	2010	2011	2012	2013
Florida	1.29	8.63	4.45	5.44	4.62	3.58	4.01	4.74
Louisiana	1.78	6.70	2.81	5.31	4.96	2.55	4.33	8.15
Texas	0.70	3.79	2.21	2.25	2.87	2.01	2.22	2.86

comparison states

	2006	2007	2008	2009	2010	2011	2012	2013
Alabama	0.79	7.97	2.60	3.49	5.55	4.99	5.28	5.69
Arizona	1.60	6.75	4.18	2.44	3.31	2.84	3.13	2.87
California	1.31	6.66	3.23	2.73	3.49	3.17	2.96	3.79
Colorado	1.93	4.97	3.88	4.61	3.15	3.10	3.80	3.29
Connecticut	1.88	17.79	6.82	5.70	8.83	8.11	6.05	10.96
Delaware	1.65	12.90	4.09	3.37	8.49	9.90	9.22	5.23
District of Columbia	1.42	8.41	1.73	1.14	10.40	7.28	7.87	11.42
Georgia	0.60	6.40	3.67	4.18	4.44	2.03	2.69	3.21
Illinois	0.00	1.50	0.20	1.10	2.03	0.93	0.83	1.72
Indiana	0.68	4.85	2.01	2.23	2.05	2.01	1.81	1.80
Iowa	0.72	5.69	3.08	2.01	2.69	2.43	4.36	3.29
Kansas	0.54	3.14	1.22	2.43	1.82	1.74	3.43	2.65
Maine	2.61	20.99	5.59	9.28	12.08	12.38	10.84	13.73
Maryland	2.81	17.81	7.07	8.62	8.64	5.06	7.98	9.56
Massachusetts	4.87	27.57	10.36	9.85	14.52	10.12	17.29	12.27
Michigan	2.81	10.34	4.97	7.53	6.49	2.58	2.55	4.37
Minnesota	0.86	3.81	1.99	1.77	2.18	1.19	2.25	2.12
Missouri	0.93	3.69	1.96	2.53	3.09	2.79	2.27	2.54
Nevada	0.61	4.96	2.19	3.06	3.25	3.10	3.63	5.44
New Hampshire	1.13	8.19	1.40	3.86	6.57	4.93	2.48	5.46
New Jersey	1.98	15.65	5.01	4.52	6.39	3.34	4.40	6.64
New York	1.24	4.99	4.00	2.90	8.62	3.01	2.51	3.10
North Carolina	3.45	12.08	5.63	6.38	8.81	6.13	5.69	7.36
Oklahoma	1.78	2.76	1.66	3.80	1.75	2.55	2.18	3.50
Oregon	2.15	5.04	3.10	3.81	4.41	3.97	4.41	4.79
Pennsylvania	2.24	12.77	5.72	5.45	7.64	7.07	7.44	7.98
Rhode Island	3.29	26.19	8.59	6.12	15.94	5.79	9.76	7.07
South Carolina	0.49	5.85	3.96	3.59	1.87	1.36	4.00	5.13
Utah	1.83	17.56	6.54	6.99	4.39	5.21	5.73	6.91

Vermont	0.59	6.30	2.38	2.40	2.77	2.56	2.67	4.53
Virginia	6.11	24.86	10.25	7.87	7.05	10.81	8.77	21.50
Wisconsin	0.86	7.89	2.16	3.62	3.20	3.26	3.66	4.05
	2006	2007	2008	2009	2010	2011	2012	2013
<i>PDMP + pain clinic law states</i>	0.81	7.27	4.98	6.34	5.85	5.86	7.69	10.18
<i>pain clinic law only states</i>	1.26	6.37	3.16	4.33	4.15	2.72	3.52	5.25
<i>comparison states</i>	1.74	10.20	4.10	4.36	5.81	4.55	5.06	6.06

Statistical analysis

Opioid prescribing rates

We modeled opioid prescribing rates in MMEs at the state level per year as the prescribing outcome because this measures simultaneously changes in the quantity and strength of opioids available to the population. In these models, our state-level time-varying characteristics included only opioid overdose death rates and the one year lag of opioid overdose rates (i.e., rates from the previous year). We included these because awareness of previous opioid overdose deaths may have effected clinical practice or policy.

Buprenorphine prescribing capacity

We conducted a sensitivity analysis including estimates for state-level per-population buprenorphine treatment capacity, calculating total number of patients who could be treated with buprenorphine for opioid use disorder based on physician waivers obtained from the Substance Abuse and Mental Health Services Administration (SAMHSA). (Substance Abuse and Mental Health Services Administration. Number of DATA-Certified Physicians. Available at http://www.samhsa.gov/medication-assisted-treatment/physician-program-data/certified-physicians?field_bup_us_state_code_value=All&=Apply. Accessed June 4, 2016.)

Overdose outcomes

The death rate outcomes have right-skewed distribution and were modeled using a generalized linear model (GLM) with gamma distribution and log link function. The models with prescribing rates as the outcome were modeled using OLS estimation, as prescribing rates in our data followed a normal distribution. Standard errors were clustered at the state level to correct for serial correlation within states over time. (see Bertrand M, Dufol E, Mullainathan S. How much should we trust differences-in-differences estimates? The Quarterly Journal of Economics. 2004; 119(1):249-275.)

Regression specifications:

specification of regression 1: Opioid prescribing rate = $a + b_1 \cdot \text{policy cat1} + b_2 \cdot \text{policy cat2} + b_3 \cdot \text{Rx opioid death rate} + b_4 \cdot \text{Rx opioid death rate}_{\text{one year lag}} + \text{year fixed effects} + \text{state fixed effects} + \text{state specific time trends} + \text{error term}$

specification of regression 2: Rx opioid death rate = $a + b_1 \cdot \text{policy cat1} + b_2 \cdot \text{policy cat2} + b_3 \cdot \text{opioid prescribing rate} + b_4 \cdot \text{pending death rate} + b_5 \cdot \text{unspecified drug overdose death rate} + \text{year fixed effects} + \text{state fixed effects} + \text{state specific time trends} + \text{error term}$

specification of regression 3: Heroin death rate= $a + b1 \cdot \text{policy cat1} + b2 \cdot \text{policy cat2} + b3 \cdot \text{opioid prescribing rate} + b4 \cdot \text{pending death rate} + b5 \cdot \text{Rx opioid death rate} + b6 \cdot \text{unspecified drug overdose death rate} + \text{year fixed effects} + \text{state fixed effects} + \text{state specific time trends} + \text{error term}$

specification of regression 4: Combined drug death rate= $a + b1 \cdot \text{policy cat1} + b2 \cdot \text{policy cat2} + b3 \cdot \text{opioid prescribing rate} + b4 \cdot \text{pending death rate} + \text{year fixed effects} + \text{state fixed effects} + \text{state specific time trends} + \text{error term}$

Note: policy cat1 is mandatory review + pain clinic law; policy cat2 is pain clinic law only

Complete regression results:

		<i>Dependent variables</i>			
		Opioid prescribing rate N=312			
<i>Independent variables:</i>		b (coefficient)	SE	P> z	95% CI
	mandatory review + pain clinic law	-80.064	34.854	0.023	-147.421 -11.752
	pain clinic law only	-54.663	59.339	0.366	-169.030 60.563
	opioid prescribing rate	N/A	N/A	N/A	N/A N/A
	pending death rate	N/A	N/A	N/A	N/A N/A
	rx_opioid_death_rate	8.016	8.266	0.332	-8.186 24.217
	lagged_rx_opioid_death_rate	5.841	5.635	0.300	-5.205 16.886
	unspecified drug death rate	N/A	N/A	N/A	N/A N/A
Year fixed effects (ref. 2006)	year_2007	43.277	27.382	0.114	-10.391 96.945
	year_2008	79.659	51.688	0.123	-21.647 180.965
	year_2009	95.752	77.462	0.216	-56.071 247.575
	year_2010	130.359	100.262	0.194	-66.151 326.869
	year_2011	108.000	123.587	0.382	-134.226 350.227
	year_2012	82.302	150.674	0.585	-213.014 377.617
	year_2013	37.840	176.892	0.831	-308.862 384.541
State fixed effects (ref. AL)	state_AZ	-95.910	30.387	0.002	-155.467 -36.353
	state_CA	-354.020	1.204	0.000	-356.379 -351.661
	state_CO	-338.889	19.570	0.000	-377.245 -300.533
	state_CT	-161.646	12.448	0.000	-186.044 -137.248
	state_DC	-636.103	7.672	0.000	-651.140 -621.066

state_DE	185.709	1.446	0.000	182.875	188.542
state_FL	109.042	67.352	0.105	-22.967	241.050
state_GA	-234.302	1.637	0.000	-237.512	-231.093
state_IA	-366.051	11.279	0.000	-388.158	-343.944
state_IL	-445.820	0.484	0.000	-446.768	-444.871
state_IN	-29.930	8.451	0.000	-46.494	-13.365
state_KS	-216.259	3.738	0.000	-223.585	-208.934
state_KY	41.241	45.840	0.368	-48.603	131.085
state_LA	-0.133	30.835	0.997	-60.569	60.303
state_MA	-305.645	23.543	0.000	-351.788	-259.503
state_MD	-247.556	19.813	0.000	-286.390	-208.723
state_ME	13.782	57.848	0.812	-99.599	127.162
state_MI	-154.713	8.277	0.000	-170.935	-138.490
state_MN	-452.402	9.760	0.000	-471.530	-433.273
state_MO	-149.302	31.654	0.000	-211.341	-87.262
state_NC	-150.659	70.747	0.033	-289.321	-11.997
state_NH	-207.146	52.516	0.000	-310.076	-104.217
state_NJ	-213.944	22.389	0.000	-257.825	-170.062
state_NV	223.692	123.672	0.070	-18.701	466.085
state_NY	-347.641	8.152	0.000	-363.619	-331.663
state_OH	-79.700	12.155	0.000	-103.525	-55.876
state_OK	-31.964	115.757	0.782	-258.843	194.915
state_OR	-19.657	56.175	0.726	-129.758	90.445
state_PA	-155.107	12.995	0.000	-180.577	-129.637
state_RI	-242.374	20.176	0.000	-281.917	-202.830
state_SC	-134.252	16.969	0.000	-167.510	-100.993
state_TN	61.045	44.227	0.168	-25.638	147.727
state_TX	-342.349	23.809	0.000	-389.014	-295.685
state_UT	-87.694	117.878	0.457	-318.732	143.343
state_VA	-314.766	12.552	0.000	-339.367	-290.165
state_VT	-320.029	64.087	0.000	-445.636	-194.421
state_WI	-288.956	30.649	0.000	-349.026	-228.885
state_WV	144.143	115.724	0.213	-82.671	370.957
_cons	743.258	71.312	0.000	603.489	883.026

state specific time trends (omitted)

Prescription opioid overdose death rate

N=312

	b (coefficient)	SE	P> z	95% CI	
mandatory review + pain clinic law	-0.206	0.081	0.011	-0.365	-0.047
pain clinic law only	-0.030	0.065	0.647	-0.158	0.098
opioid prescribing rate	0.001	0.000	0.000	0.001	0.002
pending death rate	-0.025	0.005	0.000	-0.035	-0.015

	rx_opioid_death_rate	N/A	N/A	N/A	N/A	N/A
	lagged_rx_opioid_death_rate	N/A	N/A	N/A	N/A	N/A
	unspecified drug death rate	0.000	0.043	0.992	-0.085	0.084
Year fixed effects (ref. 2006)		0.026	0.039	0.512	-0.051	0.102
	year_2007					
	year_2008	0.073	0.048	0.129	-0.021	0.168
	year_2009	0.135	0.061	0.028	0.014	0.255
	year_2010	0.182	0.068	0.008	0.048	0.316
	year_2011	0.276	0.070	0.000	0.139	0.413
	year_2012	0.310	0.074	0.000	0.166	0.454
	year_2013	0.449	0.068	0.000	0.316	0.583
State fixed effects (ref. AL)		0.426	0.089	0.000	0.253	0.600
	state_AZ					
	state_CA	0.050	0.125	0.688	-0.194	0.294
	state_CO	0.416	0.090	0.000	0.239	0.593
	state_CT	-0.483	0.126	0.000	-0.730	-0.236
	state_DC	0.610	0.263	0.020	0.095	1.125
	state_DE	-0.356	0.081	0.000	-0.515	-0.197
	state_FL	0.384	0.055	0.000	0.277	0.492
	state_GA	0.272	0.089	0.002	0.099	0.446
	state_IA	-0.038	0.187	0.839	-0.405	0.329
	state_IL	0.231	0.166	0.163	-0.094	0.555
	state_IN	-0.389	0.067	0.000	-0.519	-0.258
	state_KS	0.060	0.094	0.521	-0.124	0.244
	state_KY	0.359	0.101	0.000	0.161	0.557
	state_LA	-0.166	0.184	0.366	-0.526	0.194
	state_MA	0.385	0.196	0.049	0.001	0.768
	state_MD	0.304	0.222	0.171	-0.131	0.739
	state_ME	0.304	0.108	0.005	0.093	0.516
	state_MI	-0.038	0.071	0.591	-0.177	0.101
	state_MN	0.459	0.203	0.024	0.061	0.857
	state_MO	0.346	0.103	0.001	0.144	0.549
	state_NC	0.717	0.225	0.001	0.275	1.158
	state_NH	0.612	0.194	0.002	0.232	0.992
	state_NJ	-0.564	0.121	0.000	-0.801	-0.327
	state_NV	0.656	0.211	0.002	0.242	1.070
	state_NY	0.040	0.202	0.841	-0.356	0.437
	state_OH	0.033	0.052	0.527	-0.069	0.134
	state_OK	0.989	0.133	0.000	0.729	1.249
	state_OR	0.638	0.177	0.000	0.292	0.984
	state_PA	-0.277	0.119	0.020	-0.510	-0.045
	state_RI	0.315	0.170	0.065	-0.019	0.648
	state_SC	0.158	0.048	0.001	0.063	0.253
	state_TN	0.249	0.060	0.000	0.132	0.366

state_TX	0.197	0.143	0.168	-0.083	0.478
state_UT	1.094	0.137	0.000	0.826	1.363
state_VA	0.260	0.194	0.181	-0.121	0.641
state_VT	0.807	0.186	0.000	0.443	1.171
state_WI	0.428	0.157	0.006	0.121	0.736
state_WV	1.128	0.226	0.000	0.685	1.572
_cons	0.745	0.277	0.007	0.202	1.287

state specific time trends (omitted)

		Heroin overdose death rate				
		N=312				
		b (coefficient)	SE	P> z	95% CI	
	mandatory review + pain clinic law	-0.148	0.222	0.506	-0.584	0.288
	pain clinic law only	-0.246	0.338	0.467	-0.907	0.416
	opioid prescribing rate	-0.001	0.001	0.168	-0.002	0.000
	pending death rate	-0.018	0.011	0.112	-0.040	0.004
	rx_opioid_death_rate	0.040	0.040	0.319	-0.038	0.118
	lagged_rx_opioid_death_rate	N/A	N/A	N/A	N/A	N/A
	unspecified drug death rate	-0.002	0.058	0.979	-0.114	0.111
Year fixed effects (ref. 2006)	year_2007	0.215	0.120	0.073	-0.020	0.451
	year_2008	0.719	0.163	0.000	0.401	1.038
	year_2009	0.922	0.209	0.000	0.512	1.332
	year_2010	0.839	0.258	0.001	0.335	1.344
	year_2011	1.317	0.255	0.000	0.818	1.815
	year_2012	1.763	0.272	0.000	1.230	2.296
	year_2013	2.173	0.283	0.000	1.619	2.728
State fixed effects (ref. AL)	state_AZ	2.478	0.125	0.000	2.234	2.722
	state_CA	2.219	0.232	0.000	1.765	2.674
	state_CO	2.118	0.217	0.000	1.692	2.544
	state_CT	3.596	0.202	0.000	3.200	3.991
	state_DC	1.625	0.394	0.000	0.852	2.398
	state_DE	2.618	0.165	0.000	2.296	2.941
	state_FL	1.892	0.178	0.000	1.543	2.240
	state_GA	0.137	0.163	0.399	-0.182	0.456
	state_IA	0.051	0.281	0.855	-0.499	0.602
	state_IL	1.313	0.289	0.000	0.747	1.879
	state_IN	1.123	0.143	0.000	0.843	1.403
	state_KS	0.033	0.152	0.827	-0.265	0.331
	state_KY	-0.610	0.176	0.001	-0.956	-0.264
	state_LA	0.718	0.257	0.005	0.213	1.222

state_MA	1.669	0.288	0.000	1.106	2.233
state_MD	3.148	0.306	0.000	2.549	3.747
state_ME	1.176	0.174	0.000	0.834	1.517
state_MI	2.825	0.146	0.000	2.539	3.110
state_MN	-0.379	0.295	0.199	-0.958	0.199
state_MO	2.622	0.163	0.000	2.302	2.942
state_NC	1.733	0.342	0.000	1.062	2.403
state_NH	1.305	0.296	0.000	0.726	1.884
state_NJ	2.456	0.160	0.000	2.141	2.770
state_NV	3.041	0.406	0.000	2.245	3.837
state_NY	1.932	0.289	0.000	1.367	2.498
state_OH	2.588	0.144	0.000	2.306	2.871
state_OK	0.476	0.338	0.160	-0.188	1.139
state_OR	3.627	0.251	0.000	3.134	4.120
state_PA	2.270	0.215	0.000	1.850	2.691
state_RI	1.101	0.294	0.000	0.524	1.677
state_SC	0.288	0.140	0.039	0.015	0.561
state_TN	0.159	0.147	0.278	-0.128	0.446
state_TX	2.389	0.266	0.000	1.866	2.911
state_UT	3.221	0.334	0.000	2.566	3.876
state_VA	2.364	0.281	0.000	1.815	2.914
state_VT	0.752	0.327	0.021	0.111	1.393
state_WI	1.572	0.251	0.000	1.080	2.063
state_WV	2.146	0.518	0.000	1.130	3.162
_cons	-1.935	0.488	0.000	-2.891	-0.980

state specific time trends (omitted)

Combined drug overdose death rate

N=312

	b (coefficient)	SE	P> z	95% CI	
mandatory review + pain clinic law	-0.094	0.037	0.012	-0.167	-0.021
pain clinic law only	-0.036	0.032	0.273	-0.099	0.028
opioid prescribing rate	0.001	0.000	0.000	0.000	0.001
pending death rate	-0.024	0.004	0.000	-0.033	-0.016
rx_opioid_death_rate	N/A	N/A	N/A	N/A	N/A
lagged_rx_opioid_death_rate	N/A	N/A	N/A	N/A	N/A
unspecified drug death rate	N/A	N/A	N/A	N/A	N/A
Year fixed effects (ref. 2006)	0.058	0.022	0.010	0.014	0.101
year_2007					
year_2008	0.141	0.028	0.000	0.087	0.196
year_2009	0.189	0.043	0.000	0.105	0.272
year_2010	0.213	0.044	0.000	0.126	0.300

	year_2011	0.375	0.039	0.000	0.298	0.452
	year_2012	0.437	0.037	0.000	0.365	0.509
	year_2013	0.617	0.036	0.000	0.547	0.686
		0.276	0.013	0.000	0.249	0.302
State fixed	state_AZ					
effects (ref. AL)	state_CA	-0.082	0.060	0.169	-0.199	0.035
	state_CO	0.277	0.055	0.000	0.170	0.385
	state_CT	-0.183	0.044	0.000	-0.269	-0.098
	state_DC	0.367	0.103	0.000	0.165	0.569
	state_DE	-0.326	0.038	0.000	-0.399	-0.252
	state_FL	0.185	0.035	0.000	0.117	0.254
	state_GA	0.060	0.037	0.101	-0.012	0.133
	state_IA	-0.576	0.060	0.000	-0.694	-0.459
	state_IL	0.020	0.067	0.761	-0.111	0.152
	state_IN	-0.044	0.036	0.222	-0.115	0.027
	state_KS	-0.153	0.035	0.000	-0.222	-0.085
	state_KY	0.192	0.039	0.000	0.116	0.268
	state_LA	0.235	0.033	0.000	0.170	0.301
	state_MA	0.086	0.055	0.121	-0.022	0.194
	state_MD	0.026	0.050	0.594	-0.071	0.124
	state_ME	-0.097	0.040	0.015	-0.175	-0.019
	state_MI	-0.050	0.047	0.279	-0.141	0.041
	state_MN	-0.089	0.076	0.240	-0.237	0.059
	state_MO	0.021	0.035	0.559	-0.049	0.090
	state_NC	-0.127	0.035	0.000	-0.196	-0.059
	state_NH	-0.063	0.042	0.137	-0.145	0.020
	state_NJ	-0.346	0.029	0.000	-0.403	-0.288
	state_NV	0.225	0.054	0.000	0.119	0.330
	state_NY	-0.399	0.058	0.000	-0.512	-0.286
	state_OH	0.092	0.025	0.000	0.042	0.141
	state_OK	0.348	0.017	0.000	0.313	0.382
	state_OR	0.234	0.007	0.000	0.221	0.247
	state_PA	0.319	0.023	0.000	0.275	0.364
	state_RI	0.144	0.047	0.002	0.052	0.236
	state_SC	0.047	0.038	0.222	-0.028	0.122
	state_TN	0.008	0.036	0.820	-0.062	0.078
	state_TX	-0.116	0.049	0.017	-0.212	-0.020
	state_UT	0.574	0.006	0.000	0.562	0.586
	state_VA	-0.282	0.054	0.000	-0.387	-0.177
	state_VT	-0.012	0.051	0.818	-0.112	0.089
	state_WI	-0.197	0.053	0.000	-0.301	-0.092
	state_WV	0.430	0.043	0.000	0.345	0.515
	_cons	1.972	0.114	0.000	1.749	2.194
	state specific time trends (omitted)					

Sensitivity analysis including state-level per-population buprenorphine treatment capacity:

specification of regression 5: Opioid prescribing rate= $a + b1*\text{policy cat1} + b2*\text{policy cat2} + b3*\text{Rx opioid death rate} + b4*\text{Rx opioid death rate_one year lag} + b5*\text{treatment capacity rate} + \text{year fixed effects} + \text{state fixed effects} + \text{state specific time trends} + \text{error term}$

specification of regression 6: Rx opioid death rate= $a + b1*\text{policy cat1} + b2*\text{policy cat2} + b3*\text{opioid prescribing rate} + b4*\text{pending death rate} + b5*\text{unspecified drug overdose death rate} + b6*\text{treatment capacity rate} + \text{year fixed effects} + \text{state fixed effects} + \text{state specific time trends} + \text{error term}$

specification of regression 7: Heroin death rate= $a + b1*\text{policy cat1} + b2*\text{policy cat2} + b3*\text{opioid prescribing rate} + b4*\text{pending death rate} + b5*\text{Rx opioid death rate} + b6*\text{unspecified drug overdose death rate} + b7*\text{treatment capacity rate} + \text{year fixed effects} + \text{state fixed effects} + \text{state specific time trends} + \text{error term}$

specification of regression 8: Combined drug death rate= $a + b1*\text{policy cat1} + b2*\text{policy cat2} + b3*\text{opioid prescribing rate} + b4*\text{pending death rate} + b5*\text{treatment capacity rate} + \text{year fixed effects} + \text{state fixed effects} + \text{state specific time trends} + \text{error term}$

Note: policy cat1 is mandatory review + pain clinic law; policy cat2 is pain clinic law only; treatment capacity rate is defined as the maximum number of patients who could be treated by DATA-waivered physicians per 10,000 state residents

Regression results for sensitivity analysis:

		<i>Dependent variables</i>			
		Opioid prescribing rate N=312			
		b (coefficient)	SE	P> z	95% CI
Independent variables:					
	mandatory review + pain clinic law	-79.387	34.778	0.028	-149.792 -8.981
	pain clinic law only	-53.280	59.490	0.376	-173.710 67.150
	opioid prescribing rate	N/A	N/A	N/A	N/A N/A
	pending death rate	N/A	N/A	N/A	N/A N/A
	rx_opioid_death_rate	8.048	8.239	0.335	-8.630 24.726
	lagged_rx_opioid_death_rate	5.809	5.665	0.312	-5.660 17.278
	unspecified drug death rate	N/A	N/A	N/A	N/A N/A
	treatment capacity rate	0.394	0.615	0.526	-0.852 1.639

Year fixed effects (ref. 2006)	39.886	23.341	0.096	-7.366	87.138
year_2007					
year_2008	78.178	46.729	0.103	-16.419	172.775
year_2009	93.835	70.255	0.190	-48.389	236.059
year_2010	127.718	90.880	0.168	-56.260	311.695
year_2011	105.551	112.635	0.355	-122.466	333.568
year_2012	79.354	137.515	0.567	-199.030	357.738
year_2013	34.180	161.372	0.833	-292.500	360.859
State fixed effects (ref. AL)	-96.337	30.093	0.001	-155.318	-37.356
state_AZ					
state_CA	-354.197	1.382	0.000	-356.907	-351.488
state_CO	-339.137	19.404	0.000	-377.168	-301.105
state_CT	-163.444	14.165	0.000	-191.208	-135.681
state_DC	-636.979	8.500	0.000	-653.639	-620.319
state_DE	186.364	1.537	0.000	183.351	189.377
state_FL	108.494	67.106	0.106	-23.032	240.020
state_GA	-234.575	1.528	0.000	-237.571	-231.580
state_IA	-365.047	10.610	0.000	-385.843	-344.251
state_IL	-445.666	0.505	0.000	-446.656	-444.676
state_IN	-29.748	8.319	0.000	-46.052	-13.443
state_KS	-215.540	4.336	0.000	-224.038	-207.041
state_KY	41.950	46.519	0.367	-49.225	133.124
state_LA	-0.259	30.910	0.993	-60.843	60.324
state_MA	-307.719	22.210	0.000	-351.250	-264.189
state_MD	-249.873	18.414	0.000	-285.965	-213.782
state_ME	9.810	55.235	0.859	-98.449	118.069
state_MI	-156.342	7.534	0.000	-171.108	-141.577
state_MN	-452.043	9.492	0.000	-470.647	-433.439
state_MO	-148.947	31.956	0.000	-211.581	-86.314
state_NC	-150.153	71.195	0.035	-289.692	-10.614
state_NH	-207.337	52.412	0.000	-310.064	-104.611
state_NJ	-215.667	23.901	0.000	-262.513	-168.821
state_NV	223.402	123.537	0.071	-18.726	465.531
state_NY	-349.230	9.682	0.000	-368.207	-330.253
state_OH	-79.372	12.418	0.000	-103.711	-55.032
state_OK	-31.620	116.102	0.785	-259.176	195.936
state_OR	-19.657	56.220	0.727	-129.847	90.533
state_PA	-156.274	14.036	0.000	-183.784	-128.763
state_RI	-246.404	18.239	0.000	-282.152	-210.655
state_SC	-134.090	17.109	0.000	-167.622	-100.557
state_TN	60.878	44.174	0.168	-25.701	147.456
state_TX	-341.806	23.898	0.000	-388.645	-294.967
state_UT	-89.844	116.383	0.440	-317.949	138.262

state_VA	-314.561	12.724	0.000	-339.499	-289.623
state_VT	-323.058	61.983	0.000	-444.542	-201.575
state_WI	-289.102	30.568	0.000	-349.014	-229.190
state_WV	143.695	115.436	0.213	-82.556	369.947
_cons	742.929	71.153	0.000	603.472	882.386

state specific time trends (omitted)

Prescription opioid overdose death rate

N=312

	b (coefficient)	SE	P> z	95% CI	
mandatory review + pain clinic law	-0.206	0.082	0.011	-0.366	-0.046
pain clinic law only	-0.030	0.066	0.649	-0.159	0.099
opioid prescribing rate	0.001	0.000	0.000	0.001	0.002
pending death rate	-0.025	0.005	0.000	-0.035	-0.015
rx_opioid_death_rate	N/A	N/A	N/A	N/A	N/A
lagged_rx_opioid_death_rate	N/A	N/A	N/A	N/A	N/A
unspecified drug death rate	0.000	0.043	0.992	-0.085	0.084
treatment capacity rate	0.000	0.004	0.985	-0.009	0.009
Year fixed effects (ref. 2006)	0.026	0.054	0.627	-0.080	0.133
year_2007					
year_2008	0.074	0.054	0.175	-0.033	0.180
year_2009	0.135	0.070	0.053	-0.002	0.272
year_2010	0.182	0.077	0.019	0.030	0.334
year_2011	0.276	0.081	0.001	0.118	0.435
year_2012	0.311	0.084	0.000	0.146	0.475
year_2013	0.450	0.080	0.000	0.293	0.607
State fixed effects (ref. AL)	0.426	0.088	0.000	0.254	0.599
state_AZ					
state_CA	0.050	0.124	0.687	-0.194	0.294
state_CO	0.416	0.090	0.000	0.240	0.593
state_CT	-0.483	0.124	0.000	-0.725	-0.240
state_DC	0.610	0.261	0.019	0.099	1.121
state_DE	-0.356	0.082	0.000	-0.516	-0.196
state_FL	0.385	0.056	0.000	0.275	0.494
state_GA	0.272	0.088	0.002	0.101	0.444
state_IA	-0.038	0.191	0.841	-0.412	0.336
state_IL	0.231	0.166	0.164	-0.094	0.556
state_IN	-0.389	0.066	0.000	-0.519	-0.259
state_KS	0.060	0.096	0.531	-0.128	0.248
state_KY	0.359	0.100	0.000	0.163	0.555
state_LA	-0.166	0.184	0.368	-0.527	0.195

state_MA	0.385	0.192	0.045	0.008	0.762
state_MD	0.305	0.219	0.164	-0.124	0.733
state_ME	0.305	0.112	0.006	0.086	0.524
state_MI	-0.038	0.070	0.588	-0.174	0.099
state_MN	0.459	0.204	0.025	0.058	0.859
state_MO	0.346	0.104	0.001	0.142	0.551
state_NC	0.716	0.227	0.002	0.271	1.161
state_NH	0.612	0.194	0.002	0.231	0.992
state_NJ	-0.564	0.118	0.000	-0.795	-0.332
state_NV	0.656	0.211	0.002	0.242	1.070
state_NY	0.041	0.199	0.838	-0.350	0.431
state_OH	0.033	0.051	0.526	-0.068	0.134
state_OK	0.989	0.134	0.000	0.727	1.251
state_OR	0.638	0.177	0.000	0.291	0.985
state_PA	-0.277	0.121	0.022	-0.514	-0.040
state_RI	0.315	0.167	0.058	-0.011	0.642
state_SC	0.158	0.049	0.001	0.062	0.253
state_TN	0.249	0.060	0.000	0.132	0.366
state_TX	0.197	0.145	0.174	-0.087	0.482
state_UT	1.095	0.135	0.000	0.829	1.360
state_VA	0.260	0.195	0.183	-0.123	0.643
state_VT	0.808	0.182	0.000	0.451	1.164
state_WI	0.428	0.157	0.006	0.121	0.736
state_WV	1.128	0.226	0.000	0.685	1.572
_cons	0.745	0.278	0.007	0.200	1.290

state specific time trends (omitted)

		Heroin overdose death rate				
		N=312				
		b (coefficient)	SE	P> z	95% CI	
	mandatory review + pain clinic law	-0.158	0.226	0.484	-0.602	0.285
	pain clinic law only	-0.231	0.327	0.480	-0.873	0.410
	opioid prescribing rate	-0.001	0.001	0.153	-0.002	0.000
	pending death rate	-0.017	0.010	0.099	-0.038	0.003
	rx_opioid_death_rate	0.041	0.038	0.280	-0.034	0.117
	lagged_rx_opioid_death_rate	N/A	N/A	N/A	N/A	N/A
	unspecified drug death rate	0.001	0.059	0.990	-0.115	0.117
	treatment capacity rate	0.014	0.019	0.483	-0.025	0.052
Year fixed effects (ref. 2006)	year_2007	0.094	0.135	0.488	-0.171	0.359
	year_2008	0.662	0.129	0.000	0.409	0.915
	year_2009	0.846	0.166	0.000	0.521	1.171

	year_2010	0.743	0.206	0.000	0.340	1.146
	year_2011	1.221	0.202	0.000	0.825	1.616
	year_2012	1.649	0.209	0.000	1.238	2.060
	year_2013	2.032	0.227	0.000	1.588	2.476
		2.463	0.117	0.000	2.234	2.693
State fixed						
effects (ref. AL)	state_AZ					
	state_CA	2.213	0.226	0.000	1.770	2.656
	state_CO	2.103	0.215	0.000	1.683	2.524
	state_CT	3.533	0.218	0.000	3.106	3.961
	state_DC	1.586	0.387	0.000	0.827	2.345
	state_DE	2.644	0.173	0.000	2.306	2.982
	state_FL	1.874	0.171	0.000	1.539	2.208
	state_GA	0.119	0.160	0.456	-0.194	0.433
	state_IA	0.085	0.277	0.758	-0.458	0.628
	state_IL	1.315	0.280	0.000	0.767	1.862
	state_IN	1.132	0.134	0.000	0.870	1.394
	state_KS	0.063	0.144	0.660	-0.219	0.346
	state_KY	-0.594	0.175	0.001	-0.937	-0.252
	state_LA	0.702	0.268	0.009	0.177	1.227
	state_MA	1.584	0.285	0.000	1.024	2.143
	state_MD	3.070	0.294	0.000	2.493	3.646
	state_ME	1.034	0.197	0.000	0.649	1.420
	state_MI	2.768	0.174	0.000	2.427	3.109
	state_MN	-0.356	0.293	0.224	-0.930	0.218
	state_MO	2.637	0.165	0.000	2.314	2.960
	state_NC	1.752	0.354	0.000	1.057	2.447
	state_NH	1.304	0.291	0.000	0.732	1.875
	state_NJ	2.396	0.177	0.000	2.049	2.744
	state_NV	3.046	0.414	0.000	2.235	3.858
	state_NY	1.881	0.287	0.000	1.318	2.444
	state_OH	2.598	0.139	0.000	2.325	2.872
	state_OK	0.469	0.335	0.162	-0.189	1.126
	state_OR	3.645	0.266	0.000	3.123	4.166
	state_PA	2.224	0.257	0.000	1.719	2.729
	state_RI	1.037	0.276	0.000	0.495	1.578
	state_SC	0.296	0.130	0.023	0.041	0.552
	state_TN	0.157	0.144	0.277	-0.126	0.439
	state_TX	2.409	0.260	0.000	1.899	2.919
	state_UT	3.140	0.294	0.000	2.563	3.716
	state_VA	2.377	0.276	0.000	1.835	2.919
	state_VT	0.652	0.312	0.037	0.040	1.264
	state_WI	1.568	0.244	0.000	1.090	2.045
	state_WV	2.130	0.510	0.000	1.131	3.129
	_cons	-1.945	0.472	0.000	-2.870	-1.020

state specific time trends (omitted)

		Combined drug overdose death rate				
		N=312				
		b (coefficient)	SE	P> z	95% CI	
	mandatory review + pain clinic law	-0.095	0.036	0.009	-0.166	-0.024
	pain clinic law only	-0.034	0.032	0.286	-0.097	0.029
	opioid prescribing rate	0.001	0.000	0.000	0.000	0.001
	pending death rate	-0.024	0.004	0.000	-0.033	-0.016
	rx_opioid_death_rate	N/A	N/A	N/A	N/A	N/A
	lagged_rx_opioid_death_rate	N/A	N/A	N/A	N/A	N/A
	unspecified drug death rate	N/A	N/A	N/A	N/A	N/A
	treatment capacity rate	0.001	0.004	0.706	-0.006	0.008
Year fixed effects (ref. 2006)		0.046	0.037	0.210	-0.026	0.118
	year_2007					
	year_2008	0.136	0.034	0.000	0.069	0.203
	year_2009	0.182	0.049	0.000	0.086	0.277
	year_2010	0.204	0.053	0.000	0.100	0.307
	year_2011	0.366	0.049	0.000	0.270	0.463
	year_2012	0.427	0.049	0.000	0.331	0.522
	year_2013	0.603	0.054	0.000	0.497	0.710
State fixed effects (ref. AL)		0.274	0.013	0.000	0.248	0.300
	state_AZ					
	state_CA	-0.083	0.059	0.163	-0.200	0.034
	state_CO	0.277	0.055	0.000	0.170	0.383
	state_CT	-0.190	0.043	0.000	-0.274	-0.105
	state_DC	0.363	0.104	0.000	0.160	0.567
	state_DE	-0.323	0.039	0.000	-0.399	-0.247
	state_FL	0.184	0.035	0.000	0.115	0.252
	state_GA	0.059	0.037	0.111	-0.014	0.131
	state_IA	-0.573	0.062	0.000	-0.696	-0.451
	state_IL	0.020	0.067	0.762	-0.111	0.152
	state_IN	-0.043	0.036	0.233	-0.115	0.028
	state_KS	-0.151	0.037	0.000	-0.223	-0.080
	state_KY	0.195	0.040	0.000	0.116	0.273
	state_LA	0.235	0.033	0.000	0.170	0.300
	state_MA	0.078	0.054	0.151	-0.028	0.185
	state_MD	0.018	0.050	0.711	-0.079	0.116
	state_ME	-0.110	0.048	0.022	-0.205	-0.016
	state_MI	-0.056	0.046	0.218	-0.145	0.033
	state_MN	-0.088	0.075	0.242	-0.236	0.059

state_MO	0.022	0.036	0.549	-0.049	0.092
state_NC	-0.126	0.036	0.000	-0.196	-0.055
state_NH	-0.063	0.042	0.129	-0.145	0.018
state_NJ	-0.352	0.032	0.000	-0.414	-0.289
state_NV	0.224	0.054	0.000	0.119	0.329
state_NY	-0.405	0.057	0.000	-0.516	-0.294
state_OH	0.092	0.025	0.000	0.043	0.142
state_OK	0.349	0.018	0.000	0.313	0.385
state_OR	0.234	0.007	0.000	0.221	0.246
state_PA	0.315	0.024	0.000	0.269	0.362
state_RI	0.131	0.051	0.010	0.031	0.231
state_SC	0.047	0.039	0.221	-0.028	0.123
state_TN	0.007	0.036	0.833	-0.062	0.077
state_TX	-0.114	0.050	0.021	-0.212	-0.017
state_UT	0.566	0.022	0.000	0.522	0.610
state_VA	-0.282	0.054	0.000	-0.388	-0.175
state_VT	-0.021	0.052	0.681	-0.124	0.081
state_WI	-0.197	0.053	0.000	-0.301	-0.093
state_WV	0.429	0.044	0.000	0.343	0.515
_cons	1.971	0.114	0.000	1.747	2.195

state specific time trends (omitted)

Appendix Exhibit A1. Timing of implementation and key provisions for policies related to opioid prescribing

State	Key Statutory Provisions								
	Mandatory Prescription Drug Monitoring Program (PDMP) review ^a			Pain clinic laws					
	Operational Since	Prescribers required to register with PDMP	Prescribers required to check PDMP data prior to prescribing opioids	Operational Since	Registration, certification, licensing	Medical director required, physician on-site	Prescribing restrictions(e.g., days' supply)	Record keeping requirements	Violations and penalties
Ohio	4 th qtr, 2011	Yes	Yes	3 rd qtr, 2011	Yes	Yes	Yes	Yes	Yes
Kentucky	3 rd qtr, 2012	Yes	Yes	3 rd qtr, 2012	Yes	Yes	Yes	Yes	Yes
West Virginia	3 rd qtr, 2012	Yes	Yes	2 nd qtr, 2013	Yes	Yes	Yes	Yes	Yes
Tennessee	2 nd qtr, 2013	Yes	Yes	3 rd qtr, 2012	Yes	Yes	Yes	Yes	Yes
Louisiana	--	--	--	1 st qtr, 2007	Yes	Yes	Yes	Yes	Yes
Texas	--	--	--	4 th qtr, 2009	Yes	Yes	No	Yes	Yes
Florida	--	--	--	4 th qtr, 2010	Yes	Yes	Yes	Yes	Yes

NOTES: ^aNew York's mandated PDMP review policy was not included. It became operational in August 2013, and we lacked post-implementation data.

NOTES: States not implementing mandatory PDMP review or pain clinic laws during our study period: Alabama, Arizona, California, Colorado, Connecticut, Washington D.C., Delaware, Georgia, Iowa, Illinois, Indiana, Kansas, Massachusetts, Maryland, Maine, Michigan, Minnesota, Missouri, North Carolina, New Hampshire, New Jersey, Nevada, New York, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, Utah, Virginia, Vermont, and Wisconsin.