

Technical Appendix:

Below is additional information regarding our regression analysis, including the regression equation, number of observations, independent and dependent variables, standard errors, t-statistics, the R-squared value, and the F-statistic.

The dependent variable in this study was the rate of opioid pain reliever-related deaths per 100,000 population.

The regression was run in Stata 13.1 using the xtreg command with state fixed effects.

TECHNICAL APPENDIX EXHIBIT 1
Additional information regarding regression analysis

Independent Variable	Coefficient	Standard Error	t
PDMP Implementation Status	-1.12	0.29	-3.90
PDMP Legislative Enactment Status	0.17	0.29	0.57
State-level unemployment rate	-0.08	0.06	-1.38
State-level educational attainment rate	-0.08	0.16	-0.51
Number of years since PDMP was implemented	0.11	0.06	1.92
Year in study period	0.45	0.07	6.51

<p>N = 510 F = <0.001 R² (within) = 0.53 R² (between) = 0.02 R² (overall) = 0.27</p>
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Supplemental Appendix:

APPENDIX EXHIBIT 1

Multivariable associations of Prescription Drug Monitoring Programs and opioid-related deaths in the US without imputed data, 1999–2013

N=499

	Variable	Bivariate Coefficient (95% CI)	P-Value	Multivariable Coefficient (95% CI)	P-Value
Explanatory Variables	PDMP Implementation	2.01 (1.65 to 2.37)	<0.001	-1.09 (-1.65 to -0.55)	<0.001
	PDMP Implementation*Time	0.43 (0.33 to 0.52)	<0.001	0.12 (0.00 to 0.28)	0.05
State-Level & Time Trend Controls	PDMP legislation enactment	2.37 (2.07 to 2.66)	<0.001	0.15 (-0.42 to 0.73)	0.61
	Educational Attainment	0.98 (0.90 to 1.05)	<0.001	-0.01 (-0.33 to 0.32)	0.97
	Unemployment Rate	0.56 (0.48 to 0.64)	<0.001	-0.7 (-0.18 to 0.04)	0.21
	Linear time trend	0.33 (0.31 to 0.36)	<0.001	0.42 (0.28 to 0.56)	<0.001
<p>Source/Notes: Authors' analyses of data from National Center for Health Statistics, National Vital Statistics System, Detailed Mortality File accessed through CDC WONDER Database; American Community Census 5-year estimates; Decennial census, 2000 and 2010; Bureau of Labor Statistics; Brandeis University PDMP Training Technical Assistance Center (TTAC); Law Atlas, Prescription Monitoring Program Dataset; Montana Children, Families, Health, and Human Services Interim Committee; Personal communication with state PDMP administrators.</p> <p>Note: For each bivariate and multivariate regression, the outcome of interest is the opioid-related overdose death rate / 100,000 population. The explanatory variables, as well as the PDMP legislation enactment, are per year of implementation. State fixed effects used for all models.</p>					

APPENDIX EXHIBIT 2

Associations between PDMP Implementation, Control Structures and Opioid-related Deaths, 1999-2013

- A. All states included in analysis
- B. West Virginia is excluded from analysis
- C. Florida is excluded from analysis

	Variable	Model A Coefficient (95% CI)	P-Value	Model B Coefficient (95% CI)	P-Value	Model C Coefficient (95% CI)	P-Value
Explanatory Variables	PDMP Implementation	-1.12 (-1.68 to -0.55)	<0.001	-0.70 (-1.10 to -0.31)	0.001	-1.05 (-1.63 to -0.48)	<0.001
	PDMP*Time Interaction	0.11 (0.00 to 0.23)	0.06	-0.16 (-0.25 to -0.08)	<0.001	0.12 (0.00 to 0.23)	0.05
State-Level & Time Trend Controls	Educational Attainment	-0.08 (-0.40 to 0.24)	0.61	-0.02 (-0.24 to 0.20)	0.86	-0.11 (-0.43 to 0.21)	0.51
	Unemployment Rate	-0.08 (-0.19 to 0.03)	0.17	0.00 (-0.08 to 0.08)	0.99	-0.09 (-0.21 to 0.02)	0.12
	Legislative Enactment	0.17 (-0.40 to 0.74)	0.57	-0.03 (-0.43 to 0.37)	0.89	0.15 (-0.43 to 0.73)	0.62
	Linear Time Trend	0.45 (0.31 to 0.59)	<0.001	0.43 (0.33 to 0.52)	<0.001	0.46 (0.32 to 0.60)	<0.001
Regression Output	N	510	--	495	--	495	--
	R ² overall	0.27	--	0.33	--	0.27	--
	F-statistic	<0.001	--	<0.001	--	<0.001	--

Source: Authors' analyses of data from National Center for Health Statistics, National Vital Statistics System, Detailed Mortality File accessed through CDC WONDER Database; American Community Census 5-year estimates; Decennial census, 2000 and 2010; Bureau of Labor Statistics; Brandeis University PDMP Training Technical Assistance Center (TTAC); Law Atlas, Prescription Monitoring Program Dataset; Montana Children, Families, Health, and Human Services Interim Committee; Personal communication with state PDMP administrators

APPENDIX EXHIBIT 3

Associations between PDMP Implementation and Opioid-Related Deaths, 1999-2013

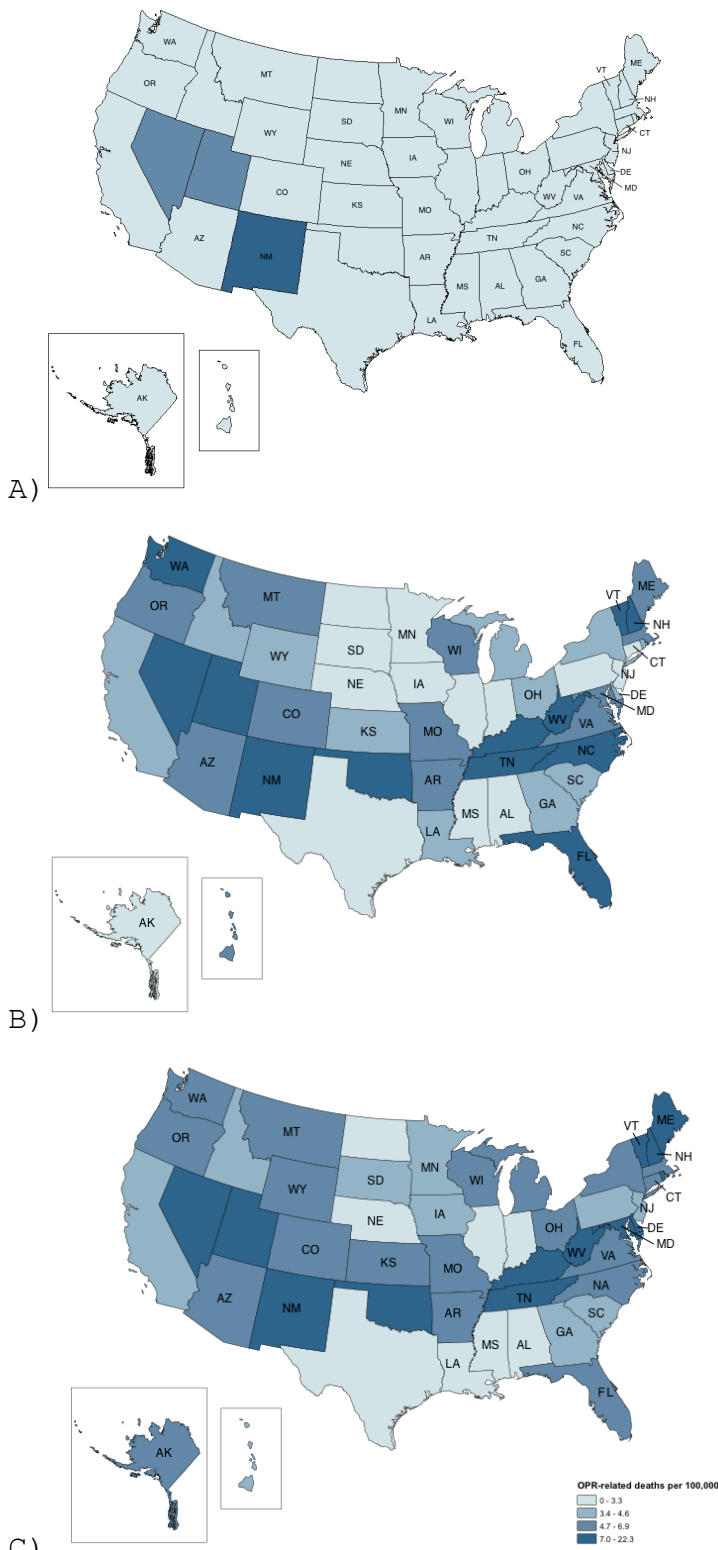
- A. Analysis does not include deaths attributed to heroin or opium
- B. Analysis does include deaths attributed to heroin or opium

	Variable	Model A Coefficient (95% CI)	P-Value	Model B Coefficient (95% CI)	P-Value
Explanatory Variables	PDMP Implementation	-1.12 (-1.68 to -0.55)	<0.001	-1.19 (-1.80 to -0.58)	0.001
	PDMP*Time Interaction	0.11 (0.00 to 0.23)	0.06	0.18 (0.05 to 0.30)	0.006
State-Level & Time Trend Controls	Educational Attainment	-0.08 (-0.40 to 0.24)	0.61	-0.24 (-0.59 to 0.10)	0.17
	Unemployment Rate	-0.08 (-0.19 to 0.03)	0.17	-0.12 (-0.24 to 0.00)	0.05
	Legislative Enactment	0.17 (-0.40 to 0.74)	0.57	0.06 (-0.56 to 0.67)	0.86
	Linear Time Trend	0.45 (0.31 to 0.59)	<0.001	0.59 (0.45 to 0.74)	<0.001
Regression Output	N	510	--	510	--
	R ² overall	0.27	--	0.26	--
	F-statistic	<0.001	--	<0.001	--

Source: Authors' analyses of data from National Center for Health Statistics, National Vital Statistics System, Detailed Mortality File accessed through CDC WONDER Database; American Community Census 5-year estimates; Decennial census, 2000 and 2010; Bureau of Labor Statistics; Brandeis University PDMP Training Technical Assistance Center (TTAC); Law Atlas, Prescription Monitoring Program Dataset; Montana Children, Families, Health, and Human Services Interim Committee; Personal communication with state PDMP administrators.

Note: For each bivariate and multivariate regression, the outcome of interest is the opioid-related overdose death rate / 100,000 population. The explanatory variables, as well as the PDMP legislation enactment, are per year of implementation. State fixed effects used for all models.

APPENDIX EXHIBIT 5. Prescription Opioid-Related Death Rate, A. 1999, B. 2007, C. 2013.



Source/Notes: Brandeis University PDMP Training Technical Assistance Center (TTAC); States labeled with their postal abbreviations are included in our study sample.

APPENDIX EXHIBIT 6

Characteristics of US states with and without an implemented Prescription Drug Monitoring Program, 1999-2013

		With Implemented PDMP Value (95% CI)	Without Implemented PDMP Value (95% CI)	P-Value*	Overall Mean
1999	Number of States	--	34	--	34
	Opioid-Related Overdose Deaths / 100,000	--	1.36 (0.91 to 2.73)	--	1.36
	Unemployment Rate	--	3.99 (3.61 to 4.36)	--	3.9
	Educational Attainment**	--	23.24 (21.72 to 24.75)	--	23.2
2000	Number of States	--	34	--	34
	Opioid-Related Overdose Deaths / 100,000	--	1.71 (1.27 to 2.16)	--	1.71
	Unemployment Rate	--	3.81 (3.46 to 4.16)	--	3.81
	Educational Attainment**	--	23.87 (22.32 to 25.41)	--	23.87
2001	Number of States	--	34	--	34
	Opioid-Related Overdose Deaths / 100,000	--	2.32 (1.81 to 2.82)	--	2.32
	Unemployment Rate	--	4.41 (4.08 to 4.73)	--	4.41
	Educational Attainment**	--	24.51 (22.93 to 26.08)	--	24.51
2002	Number of States	1	33	--	34
	Opioid-Related Overdose Deaths / 100,000	9.4 (--)	2.82 (2.23 to 3.42)	--	3.02
	Unemployment Rate	5.9 (--)	5.22 (4.83 to 5.60)	--	5.24
	Educational Attainment**	15.8 (--)	25.47 (23.91 to 27.03)	--	25.19
2003	Number of States	2	32	--	34
	Opioid-Related Overdose Deaths / 100,000	7.05 (-36.79 to 50.89)	3.25 (2.52 to 3.98)	0.02	3.47
	Unemployment Rate	5.05 (-7.02 to 17.12)	5.51 (5.12 to 5.90)	0.56	5.49
	Educational Attainment**	23.65 (-74.82 to 122.12)	25.29 (23.73 to 26.85)	0.63	25.19
2004	Number of States	3	31	--	34
	Opioid-Related Overdose Deaths / 100,000	8.03 (-3.58 to 19.64)	3.56 (2.93 to 4.19)	<0.001	3.96
	Unemployment Rate	4.53 (2.54 to 6.53)	5.14 (4.76 to 5.51)	0.34	5.08
	Educational Attainment**	25.97 (24.32 to 27.62)	24.57 (4.80 to 44.34)	0.63	25.84
2005	Number of States	6	28	--	34
	Opioid-Related Overdose Deaths / 100,000	5.17 (1.89 to 8.44)	3.91 (3.28 to 4.89)	.016	4.14
	Unemployment Rate	5.0 (3.39 to 6.61)	4.86 (4.47 to 5.26)	0.79	4.89
	Educational Attainment**	23.78 (17.71 to 29.85)	27.08 (25.32 to 28.84)	0.13	26.5
2006	Number of States	8	26	--	34
	Opioid-Related Overdose Deaths / 100,000	6.0 (2.04 to 9.96)	4.82 (4.03 to 5.61)	0.31	5.1
	Unemployment Rate	4.4 (3.34 to 5.46)	4.35 (3.98 to 4.72)	0.91	4.36
	Educational Attainment**	23.24 (19.11 to 27.36)	27.28 (25.5 to 29.06)	0.03	26.33
2007	Number of States	11	23	--	34
	Opioid-Related Overdose Deaths / 100,000	6.88 (4.03 to 9.73)	4.75 (3.89 to 5.61)	0.05	5.44
	Unemployment Rate	4.27 (3.54 to 5.00)	4.69 (3.68 to 5.69)	0.58	4.55
	Educational Attainment**	24.36 (20.75 to 27.98)	27.24 (25.39 to 29.10)	0.10	26.31

** Percent aged 25 years and older with a college degree or higher

Patrick SW, Fry CE, Jones TF, Buntin MB. Implementation of prescription drug monitoring programs associated with reductions in opioid-related deaths. Health Aff (Millwood). 2016;35(7). Published online June 22, 2016.

		With Implemented PDMP Value (95% CI)	Without Implemented PDMP Value (95% CI)	P-Value*	Overall Mean
2008	Number of States	15	19	--	34
	Opioid-Related Overdose Deaths / 100,000	6.47 (4.14 to 8.8)	5.46 (4.29 to 6.64)	5.91	0.39
	Unemployment Rate	5.41 (4.76 to 6.06)	4.98 (4.48 to 5.49)	5.17	0.28
	Educational Attainment**	25.01 (22.0 to 28.02)	27.98 (26.05 to 29.91)	0.08	26.67
2009	Number of States	17	17	--	34
	Opioid-Related Overdose Deaths / 100,000	5.35 (4.28 to 6.42)	6.14 (4.94 to 7.34)	0.31	5.75
	Unemployment Rate	8.45 (7.58 to 9.31)	7.96 (7.04 to 8.88)	0.42	8.20
	Educational Attainment**	25.81 (22.97 to 28.65)	28.15 (26.10 to 30.19)	0.17	26.98
2010	Number of States	18	16	--	34
	Opioid-Related Overdose Deaths / 100,000	6.38 (4.08 to 8.68)	5.93 (4.89 to 6.96)	0.72	6.16
	Unemployment Rate	8.7 (7.93 to 9.47)	8.2 (7.17 to 9.23)	0.41	8.46
	Educational Attainment**	26.24 (23.5 to 28.98)	28.17 (26.02 to 30.32)	0.26	27.15
2011	Number of States	22	12	--	34
	Opioid-Related Overdose Deaths / 100,000	6.41 (4.07 to 8.75)	6.25 (5.09 to 7.41)	0.92	6.36
	Unemployment Rate	7.85 (7.0 to 8.71)	7.62 (6.64 to 8.59)	0.71	7.77
	Educational Attainment**	26.87 (24.61 to 29.13)	28.61 (25.67 to 31.54)	0.33	27.48
2012	Number of States	28	6	--	34
	Opioid-Related Overdose Deaths / 100,000	5.69 (4.42 to 7.51)	5.68 (4.59 to 6.78)	0.87	5.91
	Unemployment Rate	7.09 (6.49 to 7.69)	7.13 (5.94 to 8.32)	0.95	7.1
	Educational Attainment**	6.58 (6.09 to 7.06)	5.9 (-1.72 to 13.52)	0.49	6.54
2013	Number of States	32	2	--	34
	Opioid-Related Overdose Deaths / 100,000	6.19 (4.88 to 7.50)	6.50 (-1.12 to 14.12)	0.91	6.21
	Unemployment Rate	6.58 (6.09 to 7.06)	5.90 (-1.72 to 13.52)	0.49	6.54
	Educational Attainment**	28.03 (26.21 to 29.84)	29.95 (-17.70 to 77.60)	0.60	28.14

** Percent aged 25 years and older with a college degree or higher

Sources: National Center for Health Statistics, National Vital Statistics System, Detailed Mortality File accessed through CDC WONDER Database; American Community Census 5-year estimates; Decennial census, 2000 and 2010; Bureau of Labor Statistics; Brandeis University PDMP Training Technical Assistance Center (TTAC); Law Atlas, Prescription Monitoring Program Dataset

APPENDIX EXHIBIT 7

Frequency of PDMP Control Structures for States in Sample, Selected Years.

Control Structure	2005	2007	2009	2011	2013
Number of drugs schedules monitored					
One	0	0	0	0	0
Two	0	0	0	0	1
Three	4	5	9	12	14
Four	1	4	5	7	13
Five	0	1	2	2	3
Frequency information updated in PDMP					
Less often than weekly	4	7	11	4	4
Weekly	0	1	4	15	22
More often than weekly	0	0	0	1	5
Not specified in statute	1	2	1	1	0
Prescribers must either register or use PDMP in certain situations	0	1	2	3	11
Total number of PDMPs implemented	5	10	16	21	31
Source/Notes: Authors' analyses of data from Brandeis University PDMP Training Technical Assistance Center (TTAC); Law Atlas Prescription Monitoring Program Database; Montana Children, Families, Health, and Human Services Interim Committee Note: When the frequency of updating to a PDMP was not specified in the statute, it was included in the reference category for our bivariate and multivariable models. Because we did not include West Virginia in regression model 2, we have also omitted the state here.					

APPENDIX EXHIBIT 8

Association between the number of drug schedules monitored by a PDMP and opioid-related deaths, 1999-2013

N = 495

	Variable	Model Coefficient (95% CI)	P-Value
Explanatory Variables	PDMP Implementation	0.05 (-1.65 to 1.74)	0.96
	PDMP*Time Interaction	-0.16 (-0.24 to -0.07)	<0.001
	Number of Drug Schedules Monitored	--	--
	Two	-0.57 (-3.39 to 2.24)	0.67
	Three	-0.55 (-2.25 to 1.14)	0.52
	Four	-1.04 (-2.79 to 0.71)	0.24
	Five	-1.09 (-2.96 to 0.77)	0.25
State-Level & Time Trend Controls	Educational Attainment	-0.05 (-0.28 to 0.17)	0.63
	Unemployment Rate	0.00 (-0.08 to 0.08)	0.99
	Legislative Enactment	-0.03 (-0.43 to 0.36)	0.87
	Linear Time Trend	0.44 (0.35 to 0.54)	<0.001
Regression Output	R ² overall	0.34	--
	F-statistic	<0.001	--

Source: Authors' analyses of data from National Center for Health Statistics, National Vital Statistics System, Detailed Mortality File accessed through CDC WONDER Database; American Community Census 5-year estimates; Decennial census, 2000 and 2010; Bureau of Labor Statistics; Brandeis University PDMP Training Technical Assistance Center (TTAC); LawAtlas, Prescription Monitoring Program Dataset; Montana Children, Families, Health, and Human Services Interim Committee; Personal communication with state PDMP administrators. Note: For each bivariate and multivariate regression, the outcome of interest is the opioid-related overdose death rate / 100,000 population. The explanatory variables, as well as the PDMP legislation enactment, are per year of implementation. State fixed effects used for all models.