The Complementarity of Drug Monitoring Programs and Health IT for Reducing Opioid-Related Mortality and Morbidity

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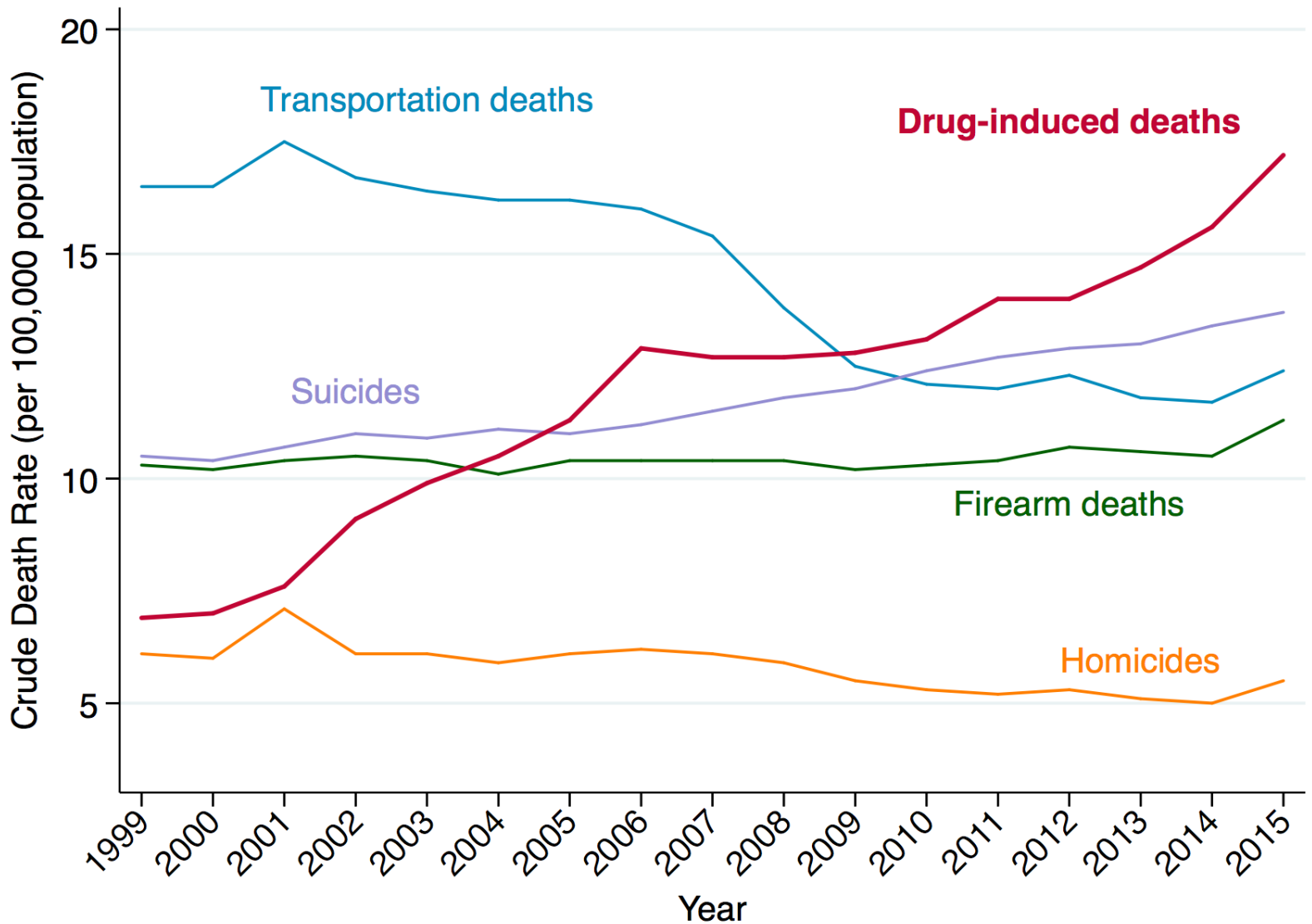
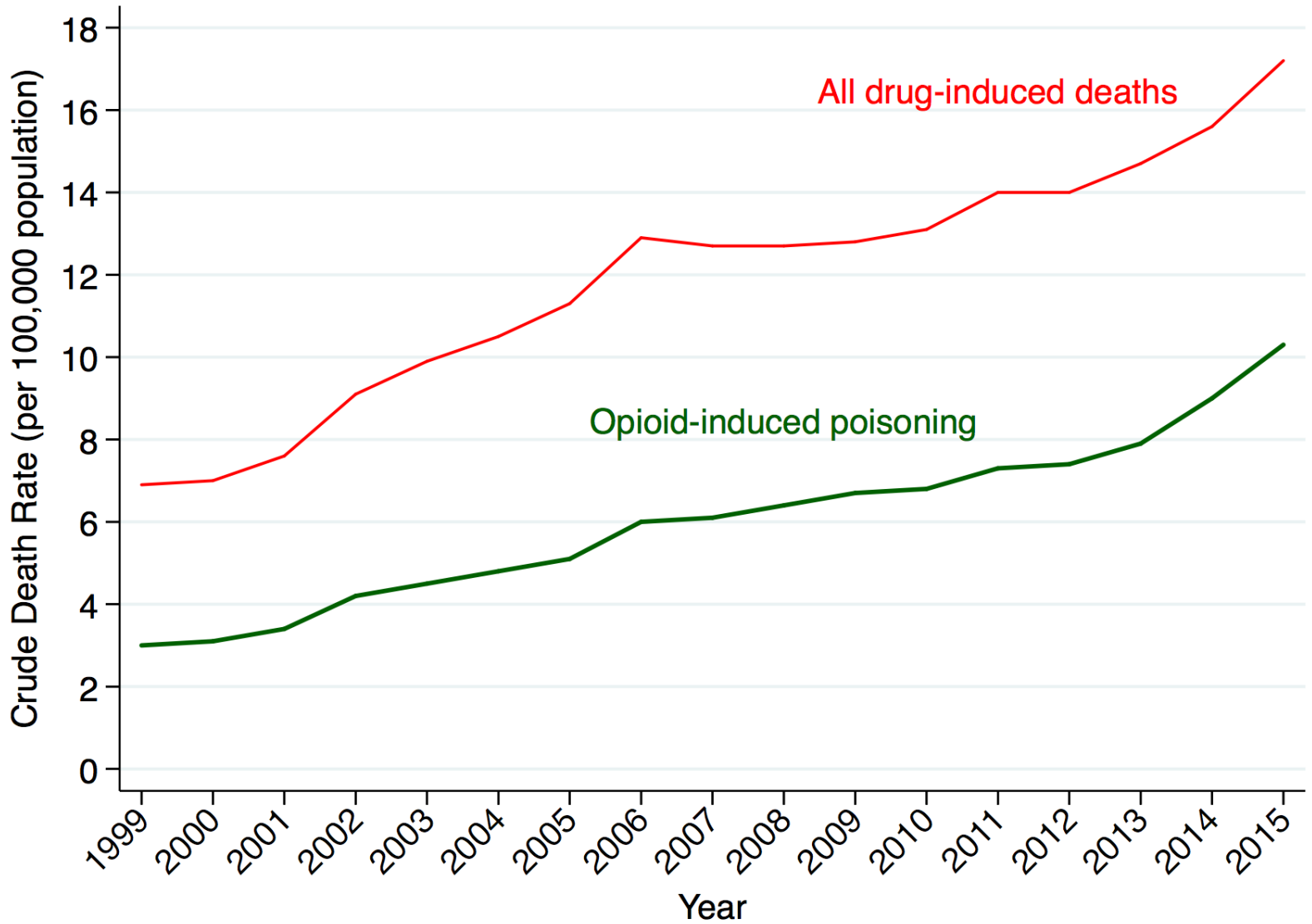
Drug Poisoning Deaths Are Increasing Sharply



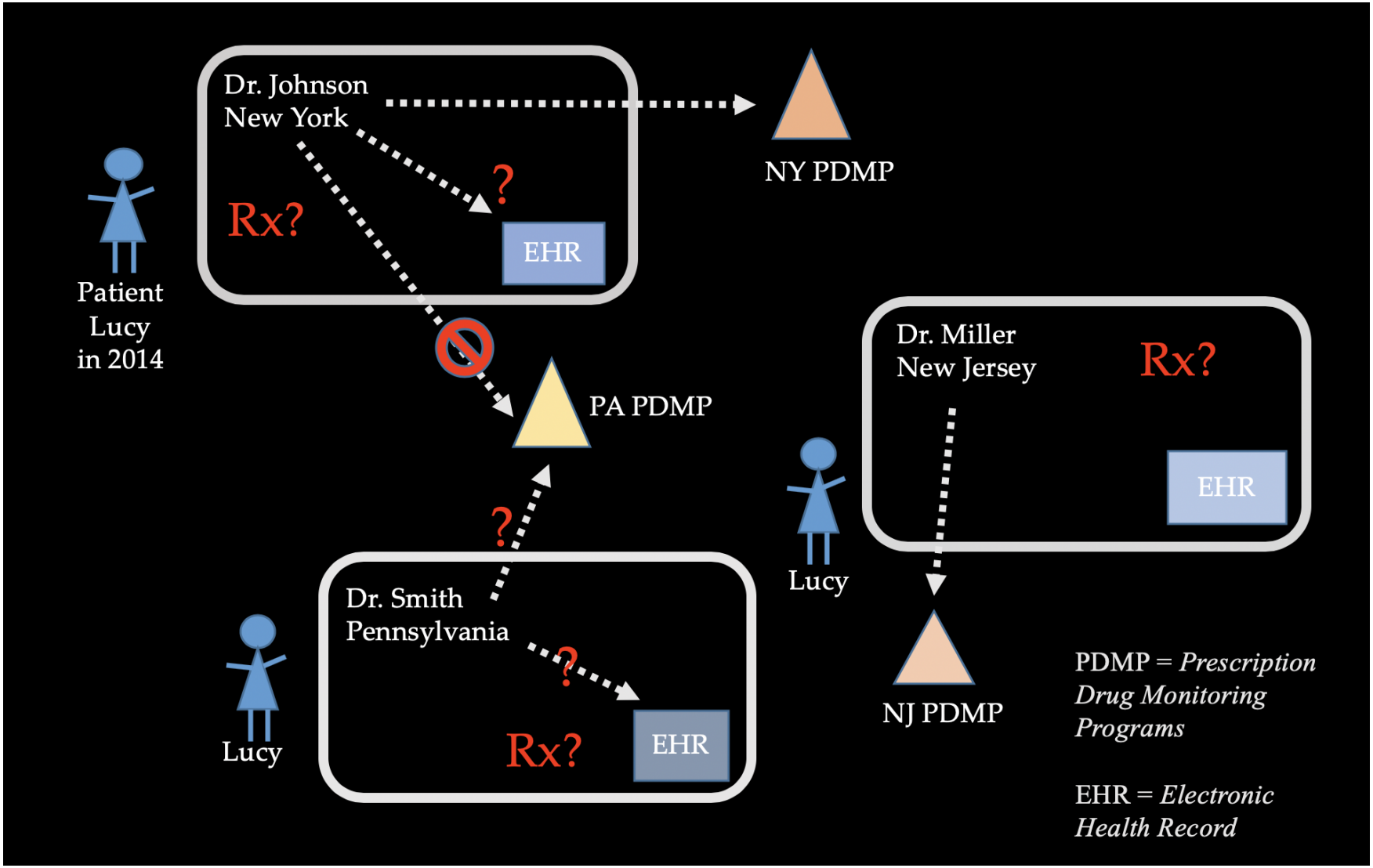
The Expanding Opioid Crisis is a Leading Force



Prescription Drug Monitoring Programs (PDMP)

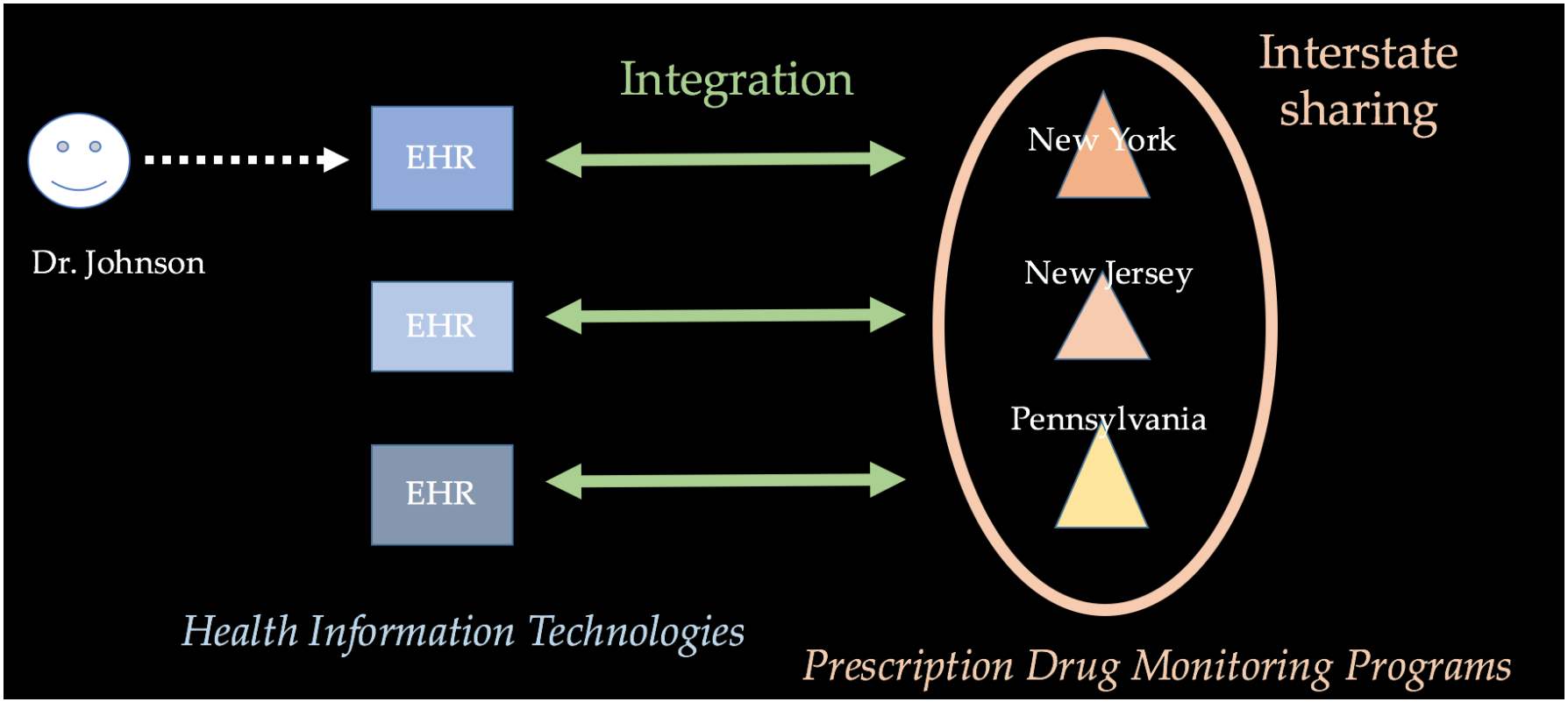
- Prescription Drug Monitoring Programs (PDMPs, or PMPs)
  - State database of controlled substances prescription history
- Authorized users can access the data to identify patients' prescription history of controlled substances
- Mixed & limited empirical evidence on PDMP effectiveness
  - Li et al. 2014, Meara et al. 2016, Kilby 2016, Dave, Grecu, & Saffer 2017, Buchmueller & Carey 2018

Problems: Doctor Shopping Across Systems & States



Focus: Health IT Policies Connecting Systems & States

- PDMP-Health IT integration connects data across systems
- Interstate hub facilitates cross-state PDMP data sharing



Research Questions

Question: Can PDMP-HIT integration reduce opioid-related mortality and morbidity?

- Study the integration policies, controlling for interstate sharing
- Evaluate the impacts to mortality & morbidity rates
- Estimate heterogeneity across stratified patient populations

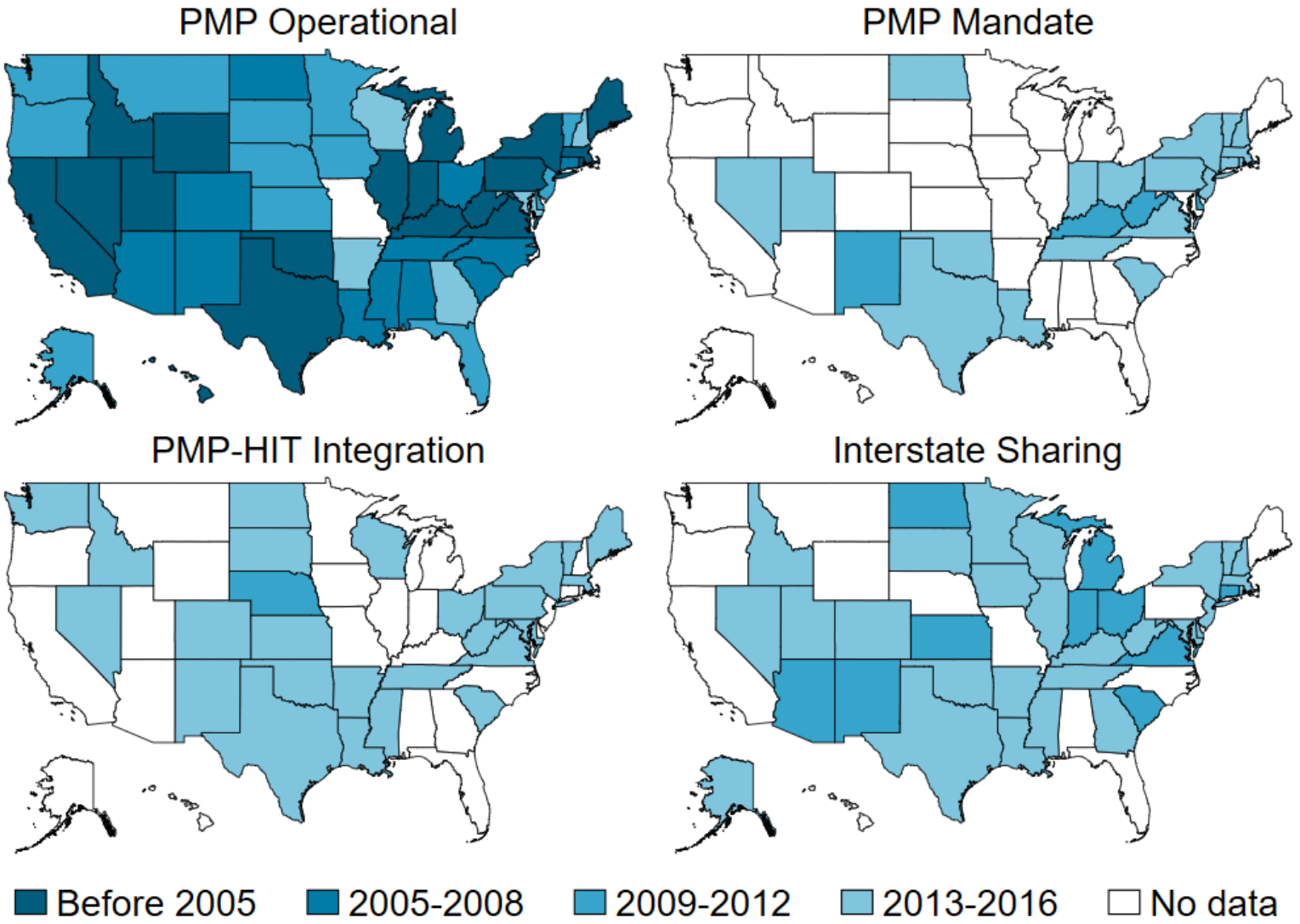
Literature Review & Contribution

- **Drug-induced crisis and drug monitoring programs**
  Case & Deaton 2015, 2017; Rutkow et al. 2015; Bao et al. 2016; Blum et al. 2016; Block et al. 2017; Buchmueller & Carey 2018
- **Digitization in health care, focus on complementarity**
  Athey & Stern 2002; Miller & Tucker 2011; Agha 2014; Dranove et al. 2014; McCullough et al. 2016; Arrow et al. 2017; Freedman et al. 2017
- The first study on the complementarity of drug monitoring & health IT on the opioid crisis across stratified samples

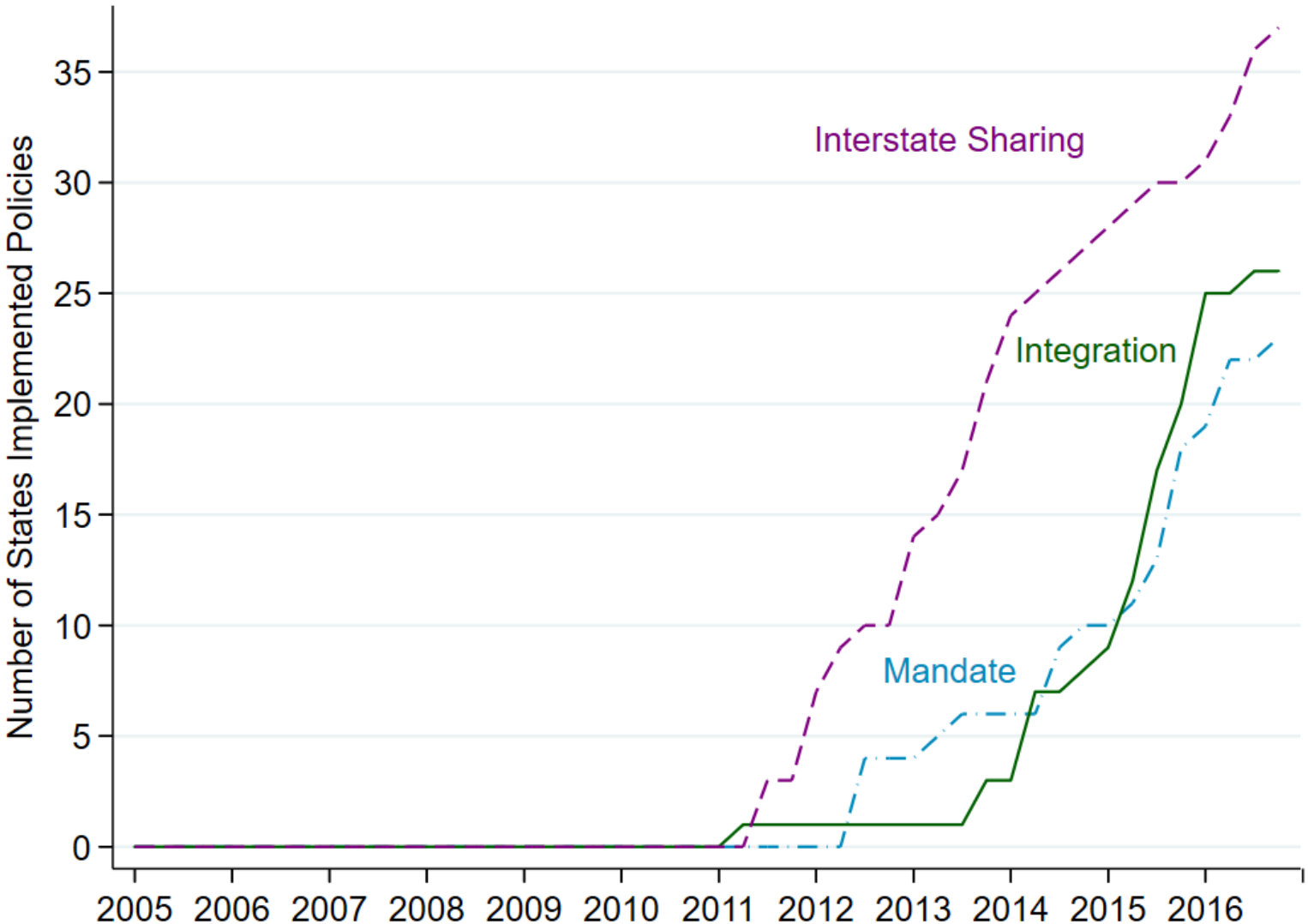
Data: PDMPs, HITs, and Health Outcomes

- State PDMP operational & mandate policy dates
  - PDAPS, NAMSDL, PDMP TTAC, statutes & admin doc
  - Discuss with lawyers and state PDMP agents
- PDMP-HIT integration, interstate sharing, & HIT adoption
  - Integration: state policy integrating PDMPs to any HITs
  - Interstate sharing: PMP InterConnect "go live" dates
  - HIT controls: state-quarter level %EHR adoption rates
- Health outcomes: US Mortality & Morbidity (ICD 9/10 coding)
  - Mortality: CDC WONDER; restricted-access death certificates (not in the final version due to Covid-related access disruption)
  - Morbidity (&mortality): Healthcare Cost & Utilization Project (HCUP)
- Opioid Rx: Automated Reports & Consolidated Ordering System
  - DEA ARCOS; morphine milligram equivalents conversion

PMP Policies & PMP-specific HIT Policies



Trends of PMP-specific HIT Policy Adoption



Diff-in-Diff. & Event Study Estimation Eqns.

- Difference-in-differences model: state-year-quarter level

$$y_{st} = \delta_s + \delta_t + \alpha PDMP_{st} + \boldsymbol{\beta} integration_{st} + \gamma mandate_{st} + \eta X_{st} + \varepsilon_{st}$$

- Assumptions: common trends & lack of common shocks

$$Event\ Study: \ y_{st} = \delta_s + \delta_t + \alpha PDMP_{st} + \sum_{j \in T} \boldsymbol{\beta_j} 1 \left\{ \begin{array}{c} integration \\ event\ time_j \end{array} \right\}_{st}$$
$$+ \gamma mandate_{st} + \eta X_{st} + \varepsilon_{st}$$

X controls for: PDMP interstate data sharing, PDMP modern system, %EHR adoption, and other policies: unemployment rate, large pill mill crackdowns, naloxone access laws, Good Samaritan overdose prevention laws, and medical marijuana dispensary laws, Medicaid expansion (Hollingsworth et al., 2017; Rees et al., 2017; Doleac & Mukherjee, 2018; Horwitz et al., 2018; Powell et al., 2018; Wen et al., 2020)

Integration reduces opioid-related inpatient rates (1/2)

Outcomes	Inpatient Overall	Inpatient rate, by age group			Inpatient rate, by expected payer		
		25–44	45–64	65+	Medicare	Medicaid	Private
Prescription drug monitoring program (PDMP)	5.053	−2.903	6.619	11.62	3.022	9.981	0.559
	(9.106)	(20.67)	(11.50)	(11.04)	(4.478)	(9.759)	(0.727)
Mandate	20.01**	59.96***	19.92*	0.837	8.291*	25.01**	−0.0242
	(8.773)	(18.70)	(11.69)	(10.78)	(4.377)	(10.14)	(0.664)
Integration	−25.88**	−25.84	−35.41***	−46.07***	−16.46***	−24.10**	−0.0964
	(10.11)	(18.79)	(12.06)	(14.00)	(5.408)	(10.15)	(0.913)
Interstate	−6.716	−9.049	−14.78	−14.39	−4.245	−1.319	−0.699
	(7.047)	(14.52)	(10.01)	(8.958)	(3.373)	(7.083)	(0.735)
LHS mean	200	289	275	228	94	99	16
N	2052	2047	2046	2018	1972	1927	1977
BS wc p-val	**0.029**	0.229	**0.011**	**0.007**	**0.020**	**0.058**	0.920S

Baseline results: esp. among vulnerable populations (2/2)

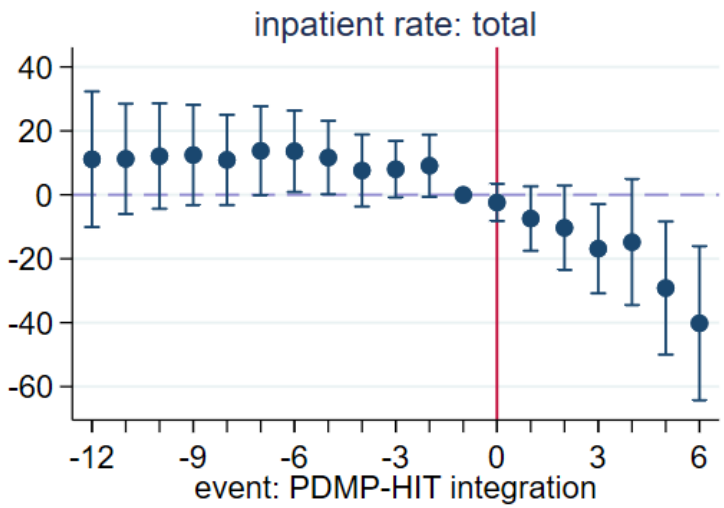
	Inpatient rate, by income quartile				ER visits	Mortality rate	
Outcomes	**Q1**	**Q2**	**Q3**	**Q4**	**Overall**	**Overall**	**Illicit/syn.**
PDMP	−14.13	−12.20	7.471	7.481	−21.52**	−0.115	−0.0380
	(19.07)	(12.49)	(8.157)	(5.639)	(10.60)	(0.196)	(0.213)
Mandate	28.88	29.38***	19.95**	1.483	32.10**	0.566***	0.520**
	(17.87)	(10.68)	(7.995)	(5.451)	(12.19)	(0.210)	(0.217)
Integration	−49.02**	−22.32*	−16.02*	−12.20**	13.57	0.128	0.111
	(22.07)	(11.84)	(8.232)	(4.715)	(10.58)	(0.211)	(0.235)
Interstate	−15.63	−6.036	−9.992	−8.709**	−2.308	−0.103	−0.191
	(14.19)	(8.476)	(6.160)	(3.391)	(8.601)	(0.159)	(0.152)
LHS mean	320	219	180	138	145	2.23	1.10
N	1833	1892	1890	1660	1424	2282	1712
BS wc p-val	**0.038**	0.121	**0.095**	**0.039**	0.243	0.574	0.687

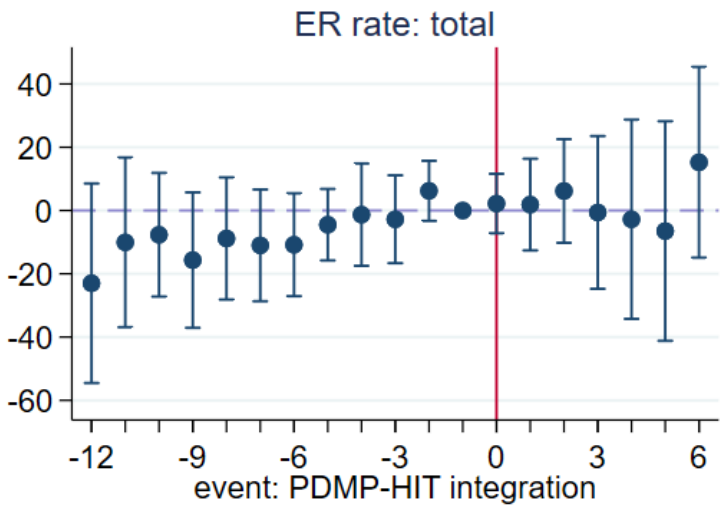
Notes: This table reports the results of the baseline model using Equation (1). Each column name represents a dependent variable in a separate regression. Fixed effects for states and year-quarters are included. Wild cluster bootstrap percentile-t *p*-values are reported in the last row (bolded for significant cases). Robust standard errors (in parentheses) are clustered at the state level.

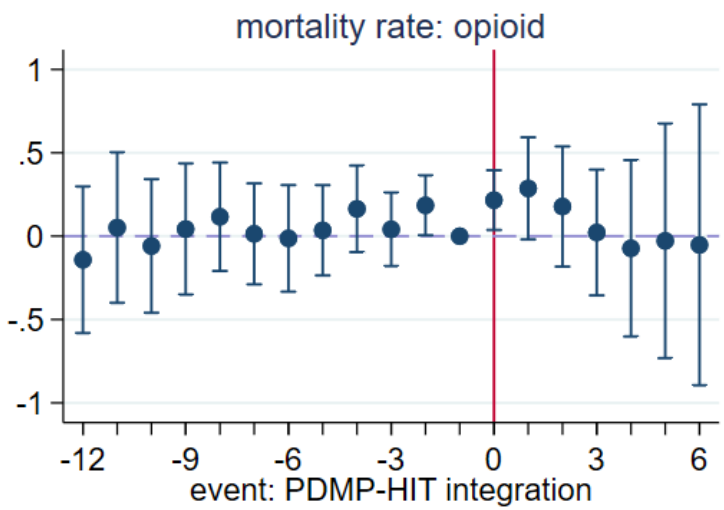
Abbreviation: LHS, left-hand side.

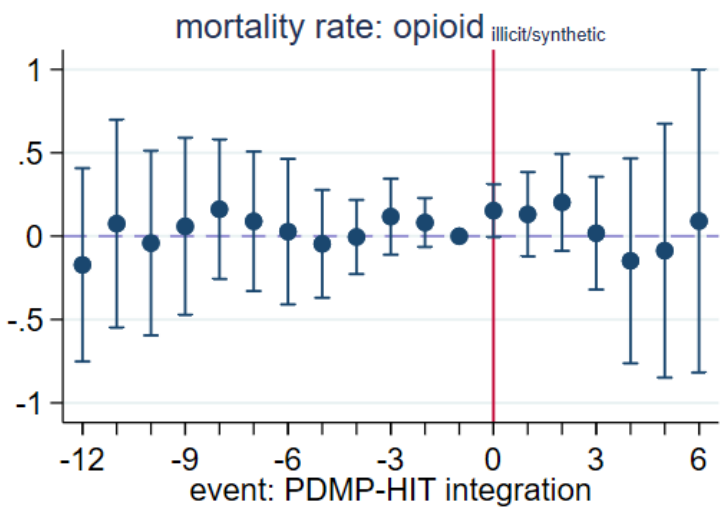
Robust *p*-values: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Event studies: results are most salient in inpatient settings









Event studies: results in stratified inpatient outcomes (1/2)

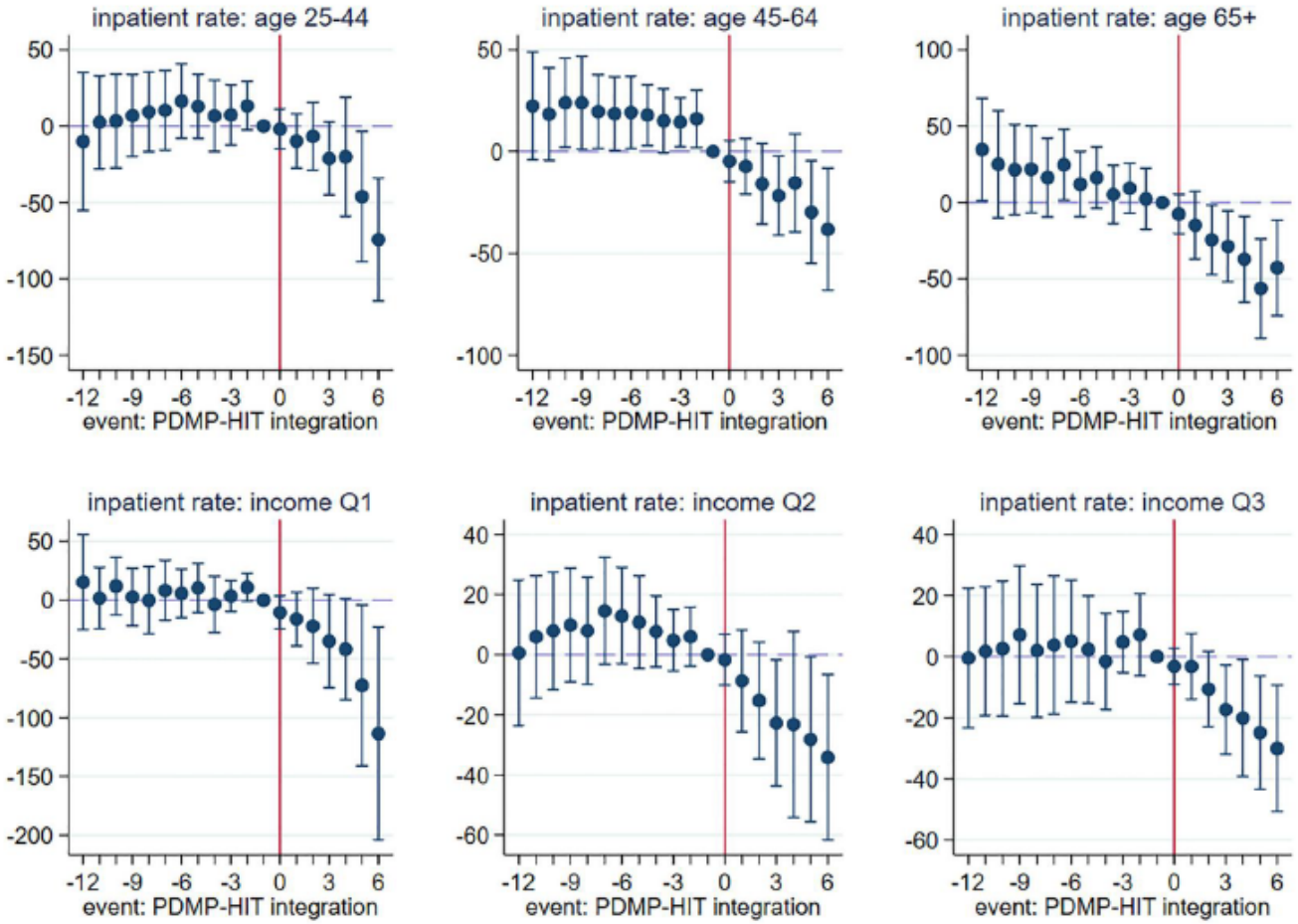
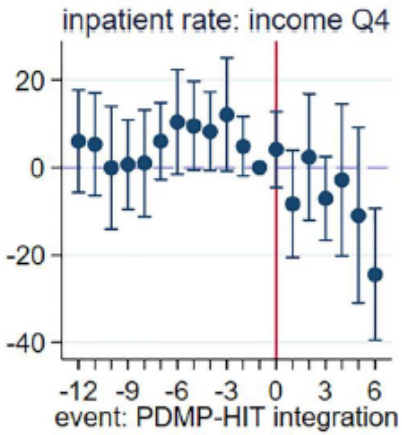
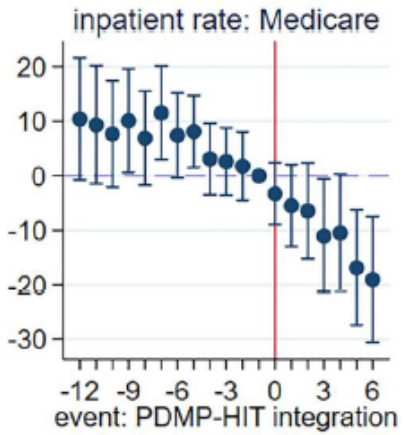
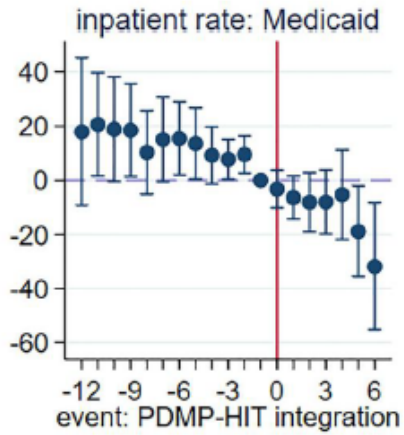


Fig 4: Event Studies: Integration on Opioid-Related Inpatient Morbidity, Stratified. Notes: These figures report event coefficient estimates using Equation (2). Outcomes are hospital inpatient discharge per 100,000, stratified by adult age group, community-level income quartile, and expected payer. The dots are point estimates of differences in outcomes between treatment and control groups 12 quarters before and 6 quarters after implementation. The whiskers present 95% confidence intervals.

Event studies: results in stratified inpatient outcomes (2/2)







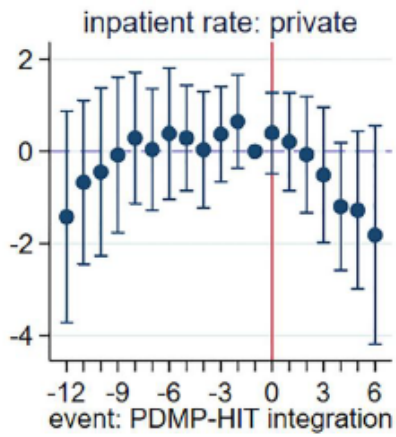


Fig 4 (cont.) Event Studies: Integration on Opioid-Related Inpatient Morbidity, Stratified. Notes: These figures report event coefficient estimates using Equation (2). Outcomes are hospital inpatient discharge per 100,000, stratified by adult age group, community-level income quartile, and expected payer. The dots are point estimates of differences in outcomes between treatment and control groups 12 quarters before and 6 quarters after implementation. The whiskers present 95% confidence intervals.

Policy Impact in States without Mandate

Outcomes	Inpatient	Inpatient rate, by age group			Inpatient rate, by expected payer		
	Overall	25–44	45–64	65+	Medicare	Medicaid	Private
Integration	−43.69***	−61.46**	−46.12***	−49.94***	−19.18***	−36.55***	−0.934
	(13.33)	(22.11)	(15.28)	(16.10)	(6.824)	(12.11)	(1.417)
Interstate	−11.70	−10.37	−25.38*	−25.99*	−5.784	−3.632	−0.360
	(9.601)	(16.58)	(14.42)	(13.81)	(4.214)	(9.979)	(1.326)
LHS mean	187	242	274	249	97	94	15
N	1108	1103	1102	1078	1076	1031	1086
	Inpatient rate, by income quartile				ER visits	Mortality rate	
Outcomes	Q1	Q2	Q3	Q4	Overall	Overall	illicit/syn.
Integration	−83.12***	−31.99**	−16.10	−17.63**	5.373	0.150	0.183
	(28.46)	(14.15)	(11.31)	(7.244)	(10.47)	(0.261)	(0.259)
Interstate	−1.330	−9.834	−24.00***	−10.12*	0.624	−0.116	−0.0736
	(19.53)	(10.46)	(7.770)	(5.142)	(5.016)	(0.156)	(0.135)
LHS mean	327	206	170	135	120	1.8	0.89
N	961	1012	1010	862	804	1237	818

Notes: This table reports the results of subsample regressions of Equation (1) in states that did not mandated PDMP access during my sample period. Only coefficients of interest are reported for simplicity. Each column name represents a dependent variable in a separate regression. Fixed effects for states and year-quarters are always included. Robust standard errors are clustered at the state level and are reported in parentheses. Abbreviation: LHS, left-hand side. Robust p-values: ***p $<$ 0.01, **p $<$ 0.05, *p $<$ 0.1.

Robustness Checks

- Integration policy interact with EHR% adoption (Table A2)
- Mechanism test: HIT mainly work in the hospitalization stage
  - ARCOS data retail volume: not explain the effect (Table A3)
- Different levels of observable controls (Table A4) and different levels of fixed effects (Table A5)
- Placebo tests: total non-opioid inpatient stays, non-opioid injury hospitalization, inpatient stays for mental health, inpatient surgery (Table A6)
- Bacon decomposition confirms the results (Table A7, Fig A2)
- Results are robust to other PDMP operational dates (Table A8)
- Other HIT controls (monetary investment in EHR) (Table A9)
- "Drop-one-state" analysis drop each implementing state (Fig A1)
- Event studies for emergency room visits (stratified) (Fig A3)

Complementarity btw integration& interstate sharing

Outcomes	Inpatient Overall	Inpatient rate, by age group			Inpatient rate, by expected payer		
		25-44	45-64	65+	Medicare	Medicaid	Private
Integration	−29.88**	−30.19	−49.27***	−61.88***	−20.29***	−21.01*	−0.730
& interstate	(11.76)	(23.63)	(15.45)	(16.32)	(6.224)	(10.95)	(1.236)
Integration	−36.02**	−43.42	−38.85*	−40.81	−18.09*	−40.64***	−0.349
only	(17.43)	(27.96)	(19.76)	(26.67)	(9.250)	(14.35)	(1.297)
Interstate	−9.535	−13.93	−15.74	−12.92	−4.718	−6.064	−0.772
only	(7.040)	(15.32)	(10.64)	(9.276)	(3.410)	(7.733)	(0.769)
LHS mean	200	289	275	228	94	99	16
N	2052	2047	2046	2018	1972	1927	1977

Outcomes	Inpatient rate, by income quartile				ER visits overall	Mortality rate	
	Q1	Q2	Q3	Q4		Overall	illicit/syn.
Integration	−59.80**	−27.98**	−25.44**	−19.59***	10.93	−0.0304	−0.120
& interstate	(24.47)	(13.12)	(9.702)	(5.914)	(15.05)	(0.298)	(0.320)
Integration	−67.33**	−23.80	−18.26	−16.46**	14.80	0.340	0.295
only	(28.86)	(21.90)	(16.25)	(7.207)	(10.62)	(0.361)	(0.315)
Interstate	−20.75	−6.446	−10.61*	−9.981***	−1.994	−0.0493	−0.158
only	(15.18)	(8.310)	(5.918)	(3.357)	(8.574)	(0.156)	(0.146)
LHS mean	320	219	180	138	145	2.23	1.10
N	1833	1892	1890	1660	1424	2282	1712

Notes: This table reports the results of estimating Equation (1) using three mutually exclusive variables. Each column name represents a dependent variable in a separate regression. Fixed effects for states and year-quarters are always included. Robust standard errors are clustered at the state level and are reported in parentheses. Abbreviation: LHS, left-hand side. Robust p-values: ***p $<$ 0.01, **p $<$ 0.05, *p $<$ 0.1.

Conclusions & Extensions

- Integration reduces opioid-related inpatient morbidity
  - Substantial in states with voluntary access PDMPs
  - Mechanism through better use of inpatient EHRs
  - Interstate sharing further complements integration
- Broadly: technology-oriented health policy designs
  - e-Rx of opioids, direct-to-consumer apps, blockchain

Table A1: HCUP opioid data availability (by group)

State	Opioid-Related Inpatient Stays					Opioid-Related Emergency Room Visits				
	Total	Ages	Income	Insurer	Location	Total	Ages	Income	Insurer	Location
AR	05-16	05-16	06-16	05-16	05-16	13-16	13-16	13-16	13-16	13-16
AZ	05-16	05-16	06-16	05-16	05-16	05-16	05-16	06-16	05-16	05-16
CA	05-16	05-16	06-16	05-16	05-16	05-16	05-16	06-16	05-16	05-16
CO	05-16	05-16	06-16	05-16	05-16	NA	NA	NA	NA	NA
CT	05-16	05-16	06-16	NA	05-16	05-16	05-16	06-16	NA	05-16
DC	13-16	13-16	13-16	NA	13-16	14-16	14-16	14-16	NA	14-16
FL	05-16	05-16	06-16	05-16	05-16	05-16	05-16	06-16	05-16	05-16
GA	05-16	05-16	06-16	05-16	05-16	05-16	05-16	06-16	05-16	05-16
HI	05-16	05-16	06-16	05-16	05-16	05-16	05-16	06-16	05-16	05-16
IA	05-16	05-16	06-16	05-16	05-16	05-16	05-16	06-16	05-16	05-16
IL	05-16	05-16	06-16	05-16	05-16	09-16	09-16	09-16	09-16	09-16
IN	05-16	06-16	06-16	05-16	05-16	05-16	05-16	06-16	05-16	05-16
KS	05-16	05-16	06-16	05-16	05-16	05-16	05-16	06-16	05-16	05-16
KY	05-16	05-16	06-16	05-16	05-16	08-16	08-16	08-16	08-16	08-16
LA	08-16	08-16	08-16	08-16	08-16	NA	NA	NA	NA	NA
MA	05-16	05-16	06-16	05-16	05-16	05-16	05-16	06-16	05-16	05-16
MD	05-16	05-16	06-16	05-16	05-16	05-16	05-16	06-16	05-16	05-16
ME	06-16	06-16	06-16	06-16	06-16	06-16	06-16	06-16	06-16	06-16
MI	05-16	05-16	06-16	05-16	05-16	NA	NA	NA	NA	NA
MN	05-16	06-16	05-16	05-16	05-16	05-16	05-16	05-16	05-16	05-16
MO	05-16	05-16	06-16	05-16	05-16	05-16	05-16	06-16	05-16	05-16
MS	13-16	13-16	13-16	13-16	13-16	16	16	16	16	16
MT	09-16	09-16	09-16	09-16	09-16	14-16	14-16	14-16	14-16	14-16
NC	05-16	05-16	06-16	05-16	05-16	07-16	07-16	07-16	07-16	07-16

Notes: During the sample period, 46 states participated in the State Inpatient Database and 35 states participated in the HCUP State Emergency Department Database, as listed above. This table records total opioid-related discharge data availability information at outcome group-level. There is different degree of missing across stratified outcomes. A color-coded spreadsheet documenting variable-level data availability is available upon request. (only upper panel is reported here due to space limit)

Table A2: integration interact w EHR% adoption

Table A2: Integration Policy interact with EHR% Adoption

outcomes	inpatient	inpatient rate, by age group			inpatient rate, by expected payer		
	overall	25-44	45-64	65+	Medicare	Medicaid	Private
integration	-31.09**	-32.96	-42.08***	-53.40***	-19.09***	-28.72**	-0.0541
xEHR%	(12.79)	(23.42)	(15.44)	(18.54)	(7.065)	(13.13)	(1.163)
interstate	-5.756	-8.408	-13.00	-11.30	-3.102	-1.866	-0.541
	(7.112)	(14.54)	(9.944)	(9.520)	(3.461)	(7.170)	(0.746)
N	2,052	2,047	2,046	2,018	1,972	1,927	1,977
outcomes	inpatient rate, by income quartile				ER visits	mortality rate	
	Q1	Q2	Q3	Q4	overall	overall	illicit/syn.
integration	-61.70**	-27.29*	-17.57	-13.63**	17.74	0.161	0.151
xEHR%	(28.84)	(14.82)	(10.63)	(6.000)	(13.51)	(0.271)	(0.274)
interstate	-13.28	-5.864	-9.488	-8.007**	-2.157	-0.105	-0.200
	(14.16)	(8.212)	(6.100)	(3.386)	(8.436)	(0.156)	(0.148)
N	1,833	1,892	1,890	1,660	1,424	2,282	1,712

Notes: This table reports the re-estimated results of the baseline model using equation 1 replace the integration and HIT control variables with integration interacting with HIT, where HIT is measured as % of state-quarter EHR adoption (0-1). Only coefficients of interest are reported for simplicity. Each column name represents a dependent variable in a separate regression. Fixed effects for states and year-quarters are always included. Robust standard errors are clustered at the state level and are reported in parentheses. Robust p-values: *** p<0.01, ** p<0.05, * p<0.1.

Table A3: mechanism test: ARCOS outcomes

outcomes (drug code)	aggregate (MME v1)	aggregate (MME v2)	r9050 codeine	r9064 buprenorphine	r9143 oxycodone	r9150 hydromorphone
PDMP	-702,932	-667,951	-22,372*	-3,543	-149,193	-1,426
	(504,626)	(431,793)	(12,547)	(4,655)	(124,403)	(1,745)
mandate	-1.028e+06**	-900,359**	-11,494	-10,468***	-280,859**	-1,241
	(430,758)	(361,228)	(13,745)	(3,710)	(139,136)	(2,101)
integration	-352,979	-275,396	-52.09	-932.9	-7,903	-1,614**
	(331,316)	(267,134)	(11,986)	(3,022)	(64,945)	(787.0)
interstate	122,341	8,794	-19,582	2,497	-11,394	1,261
	(301,250)	(241,204)	(19,597)	(2,885)	(69,434)	(1,097)
LHS mean	2,948,618	2,517,987	112,827	13,623	455,699	10,842
N	2,448	2,448	2,448	2,448	2,448	2,448
outcomes	r9193 Hydrocodone	r9230 Meperidine	r9250B Methadone	r9300 Morphine	r9801 Fentanyl Base	
PDMP	-60,108	-4,249	-8,745	-23,218	-3,279	
	(79,339)	(4,877)	(24,001)	(29,272)	(2,983)	
mandate	-126,498*	-2,572	-31,866	-20,240	456.3	
	(72,592)	(4,181)	(20,506)	(32,476)	(861.4)	
integration	-36,198	-3,990	-19,396	-7,636	-644.7	
	(47,776)	(3,805)	(19,087)	(17,383)	(1,074)	
interstate	-87,631	-4,468	28,387	-3,397	-1,824	
	(52,574)	(3,929)	(19,025)	(26,131)	(1,670)	
LHS mean	286,482	15,953	107,658	173,664	4,199	
N	2,448	2,448	2,448	2,448	2,448	

Notes: The overall opioid prescription aggregates individual ones using Morphine Milligram Equivalent (MME) conversion factors based on CMS recommendations and Piper et al (2018). The MME factors used are: codeine 0.15, buprenorphine 10, oxycodone 1.5, hydromorphone 4, hydrocodone 1, meperidine 0.1, methadone 12 or 8, morphine 1, fentanyl base 75. As the aggregate MME for Methadone can take 12 or 8 (Narcotic Treatment Programs or other sources), both are calculated and reported in the first two columns, respectively. Fixed effects for states and year-quarters are always included. Robust standard errors are clustered at the state level and are reported in parentheses. Robust p-values: *** p<0.01, ** p<0.05, * p<0.1.

Table A4: using different levels of observables

Table A4: Policy Impacts with Different Levels of Observable Controls
(Testing Confounding Policies & Demographic Controls)

outcomes	inpatient	inpatient rate, by age group			inpatient rate, by expected payer		
	overall	25-44	45-64	65+	Medicare	Medicaid	Private
1) limited observable controls (PDMP/HIT only)							
integration	-28.98***	-39.52**	-40.07***	-37.15*	-13.43**	-26.37**	-0.404
	(10.60)	(19.22)	(13.56)	(18.48)	(6.188)	(10.36)	(0.922)
interstate	-6.536	-5.547	-11.05	-20.39	-6.602	1.347	-0.359
	(8.619)	(18.02)	(11.58)	(15.66)	(4.892)	(9.734)	(0.966)
2) adding policy controls to 1)							
integration	-26.28**	-33.18*	-38.08***	-36.32*	-13.81**	-25.29**	-0.268
	(10.55)	(19.04)	(13.23)	(18.56)	(6.388)	(10.44)	(0.984)
interstate	-7.599	-7.048	-12.33	-20.78	-6.586	-0.180	-0.258
	(8.048)	(16.91)	(10.99)	(13.58)	(4.750)	(9.086)	(0.794)
3) adding demographic controls to 1)							
integration	-28.07**	-29.61	-37.47***	-49.32***	-15.96***	-26.72**	-0.206
	(10.54)	(18.65)	(12.79)	(14.17)	(5.338)	(10.44)	(0.899)
interstate	-4.618	-6.081	-12.01	-10.27	-3.560	2.550	-0.865
	(7.183)	(14.95)	(10.00)	(9.214)	(3.308)	(7.949)	(0.894)

Notes: This table reports the results of estimating equation 1 with two-way fixed effects but without extensive observable controls. Compared to the main model, panel 1) reports results where only the most relevant baseline PDMP and HIT controls are included (PDMP operational, modern system operational, mandate, EHR). Panel 2) adds to 1) widely used macro condition and policy controls (unemployment rate, pill mill bill, Medicaid expansion, Naloxone access laws, Good Samaritan laws, Medical Marijuana laws effective and dispensary openings). Panel 3) adds to 1) a set of demographic controls: the shares of population of different age groups (1-24, 25-44, 45-64, 65+) and shares of white and black populations. Robust standard errors are clustered at the state level and are reported in parentheses. Robust p-values: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. (only upper panel is reported here due to space limit)

Table A5: using different levels of fixed effects

Table A5: Results with Different Levels of Fixed Effects Controls

outcomes	inpatient	inpatient rate, by age group			inpatient rate, by expected payer		
	overall	25-44	45-64	65+	Medicare	Medicaid	Private
1) no fixed effects							
integration	-9.164	-18.33	-8.786	4.003	-1.874	-17.64*	1.191
	(11.00)	(17.82)	(13.98)	(19.49)	(6.700)	(9.306)	(0.911)
interstate	-6.506	-5.690	-12.40	-18.88	-5.692	-0.788	-0.467
	(8.996)	(16.83)	(12.21)	(13.40)	(4.659)	(9.298)	(0.812)
2) only state fix effects							
integration	-10.42	-12.75	-8.487	-13.00	-6.464	-17.18*	1.131
	(11.75)	(18.96)	(14.60)	(19.00)	(6.866)	(9.470)	(0.958)
interstate	-5.597	-5.925	-12.11	-14.51	-3.832	0.415	-0.448
	(8.712)	(15.70)	(12.41)	(12.64)	(4.295)	(8.019)	(0.798)
3) only year-quarter fixed effects							
integration	-26.34***	-31.03	-37.79***	-38.60**	-14.64***	-25.19**	-0.164
	(10.05)	(18.98)	(12.26)	(15.66)	(5.591)	(10.11)	(0.929)
interstate	-6.816	-6.678	-13.22	-18.83*	-6.158	-1.669	-0.564
	(7.722)	(16.43)	(10.24)	(10.46)	(3.903)	(8.779)	(0.765)

Notes: This table reports the results of re-estimating equation 1 with different levels of fixed effects. Instead of two-way fixed effects, panel 1) reports estimating equation 1 without any fixed effects, panel 2) reports adding only state-level fixed effects, and panel 3) reports adding back only year-quarter fixed effects. Robust standard errors are clustered at the state level and are reported in parentheses. Robust p-values: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. (only upper panel is reported here due to space limit)

Table A6: estimation on placebo outcomes

Table A6: Estimating Policy Impacts on Placebo Outcomes

inpatient outcomes	opioid-related	total non-opioid	non-opioid injury	non-opioid mental health /substance use	inpatient surgery
integration	-25.88**	-13.16	6.459**	2.150	-7.583
	(10.11)	(18.14)	(2.475)	(4.166)	(5.489)
interstate	-6.716	6.814	1.865	-0.0333	5.012
	(7.047)	(12.51)	(2.516)	(2.846)	(6.906)
LHS mean	200	1185	80	96	580
N	2,052	2,000	1,993	1,976	2,000

Notes: This table reports the baseline results of the integration policy and interstate sharing on inpatient outcomes and the re-estimated coefficients using placebo outcome variables. Each column reports the results of a separate regression. All dependent variables are discharge rates per 100,000 population. Fixed effects for states and year-quarters are always included. Robust standard errors are clustered at the state level and are reported in parentheses. Robust p-values: *** p<0.01, ** p<0.05, * p<0.1.

Table A7: Bacon decomposition results

Table A7: Bacon Decomposition Results

values/outcomes	coeff.	weight	coeff.	weight	coeff.	weight
	inpatient, overall		inpatient, age 25-44		inpatient, age 45-64	
Timing Groups	-30.89	0.28	-60.81	0.28	-31.94	0.28
Never vs Timing	-26.02	0.65	-24.15	0.65	-38.81	0.65
Within	4.67	0.07	51.93	0.07	21.08	0.07
	inpatient, age 65+		inpatient, income Q1		inpatient, income Q2	
Timing Groups	-19.97	0.28	-44.71	0.20	-42.09	0.29
Never vs Timing	-45.16	0.65	-36.13	0.75	-21.45	0.62
Within	-63.81	0.07	-28.37	0.05	27.77	0.09
	inpatient, income Q3		inpatient, income Q4		inpatient, Medicare	
Timing Groups	-15.72	0.28	-8.40	0.27	-13.45	0.34
Never vs Timing	-16.19	0.64	-12.65	0.66	-13.48	0.58
Within	-8.30	0.08	21.55	0.07	-38.32	0.08
	inpatient, Medicaid		inpatient, private			
Timing Groups	-24.51	0.35	-1.47	0.32		
Never vs Timing	-21.89	0.57	-0.09	0.60		
Within	-43.20	0.08	5.51	0.08		

Notes: The table reports Bacon decomposition (2018) for each of the main inpatient analyses. The results are directly comparable to the benchmark results in Table 3, and estimated using the same specification with two-way fixed effects and full set of control variables as in equation 1.

Table A8: using other PDMP operational controls

Table A8: Estimating Main Results using Other PDMP Operational Controls

outcomes	inpatient	inpatient rate, by age group			inpatient rate, by expected payer		
	overall	25-44	45-64	65+	Medicare	Medicaid	Private
1) PDMP operational (use baseline regular operational only)							
integration	-24.59**	-23.37	-34.06***	-44.63***	-15.93***	-23.45**	0.0739
	(10.18)	(18.88)	(12.00)	(13.90)	(5.382)	(10.42)	(0.937)
2) PDMP operational (use Horwitz "modern system operational" only)							
integration	-25.00**	-26.35	-34.26***	-44.29***	-15.95***	-22.58**	0.00182
	(10.02)	(18.63)	(11.83)	(13.83)	(5.329)	(10.13)	(0.936)
3) PDMP operational from NAMSDL (enactment)							
integration	-24.71**	-24.15	-34.65***	-44.69***	-16.11***	-22.24**	0.0613
	(10.15)	(18.59)	(12.09)	(14.18)	(5.443)	(9.854)	(0.947)
4) PDMP operational from PDAPS							
integration	-24.59**	-23.19	-34.41***	-44.62***	-15.97***	-23.31**	0.0778
	(10.16)	(18.74)	(12.02)	(13.89)	(5.372)	(10.40)	(0.938)
5) PDMP operational from Brandeis TCAA							
integration	-24.49**	-23.24	-33.88***	-44.57***	-15.97***	-23.31**	0.0778
	(10.17)	(18.82)	(11.96)	(13.89)	(5.372)	(10.40)	(0.938)

Notes: This table reports the re-estimated results of the baseline model using different data sources for the control variable of PDMP operational status. While the main specification controls for both the regular operational dates (cross-checked from NAMSDL, PDAPS, TCAA, legal documents, and communication) and Horwitz dates, this table reports results in panel 1)-5) using dates from one of the different sources. Robust standard errors are reported in parentheses. Robust p-values: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. (only upper panel is reported here due to space limit)

Table A9: other HIT controls: monetary investments

Table A9: Alternative HIT Controls: Monetary Investments

outcomes	inpatient	inpatient rate, by age group			inpatient rate, by expected payer		
	overall	25-44	45-64	65+	Medicare	Medicaid	Private
1) cumulative HIT payment							
EHR grants	-2.18e-08	-3.67e-08	-6.56e-08	-1.68e-08	-2.60e-09	-1.29e-08	2.01e-09
	(2.96e-08)	(5.89e-08)	(4.73e-08)	(3.29e-08)	(1.55e-08)	(2.95e-08)	(2.74e-09)
integration	-27.43***	-27.70	-39.47***	-48.74***	-17.07***	-24.55**	-0.0734
	(9.965)	(18.65)	(12.19)	(14.80)	(5.707)	(9.872)	(0.876)
interstate	-7.547	-11.44	-18.04*	-12.66	-3.366	-2.970	-0.374
	(7.340)	(14.74)	(10.60)	(10.20)	(3.514)	(7.312)	(0.693)
2) per capita HIT payment							
EHR $ p.c.	-2.02e-06	1.17e-05	-5.74e-06	-1.20e-05	-3.05e-06	-2.12e-06	-2.83e-07
	(6.06e-06)	(1.31e-05)	(7.08e-06)	(7.70e-06)	(3.04e-06)	(6.68e-06)	(5.34e-07)
integration	-25.88**	-29.55	-34.89***	-44.35***	-16.08***	-23.19**	-0.0962
	(10.32)	(18.85)	(12.59)	(14.88)	(5.633)	(10.85)	(0.917)
interstate	-5.392	-11.70	-11.69	-8.299	-2.355	-1.494	-0.458
	(6.776)	(13.98)	(9.596)	(9.214)	(3.513)	(6.776)	(0.687)

Notes: This table reports the results of estimating equation 1 with HIT control variable replaced by monetary HIT investment (cumulative or per capita) proxies by EHR incentive payments to eligible hospitals. Only relevant coefficients are reported for simplicity. Fixed effects for states and year-quarters are always included. Robustness standard errors are clustered at the state level and are reported in parentheses. Robust p-values: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. (only upper panel is reported here due to space limit)

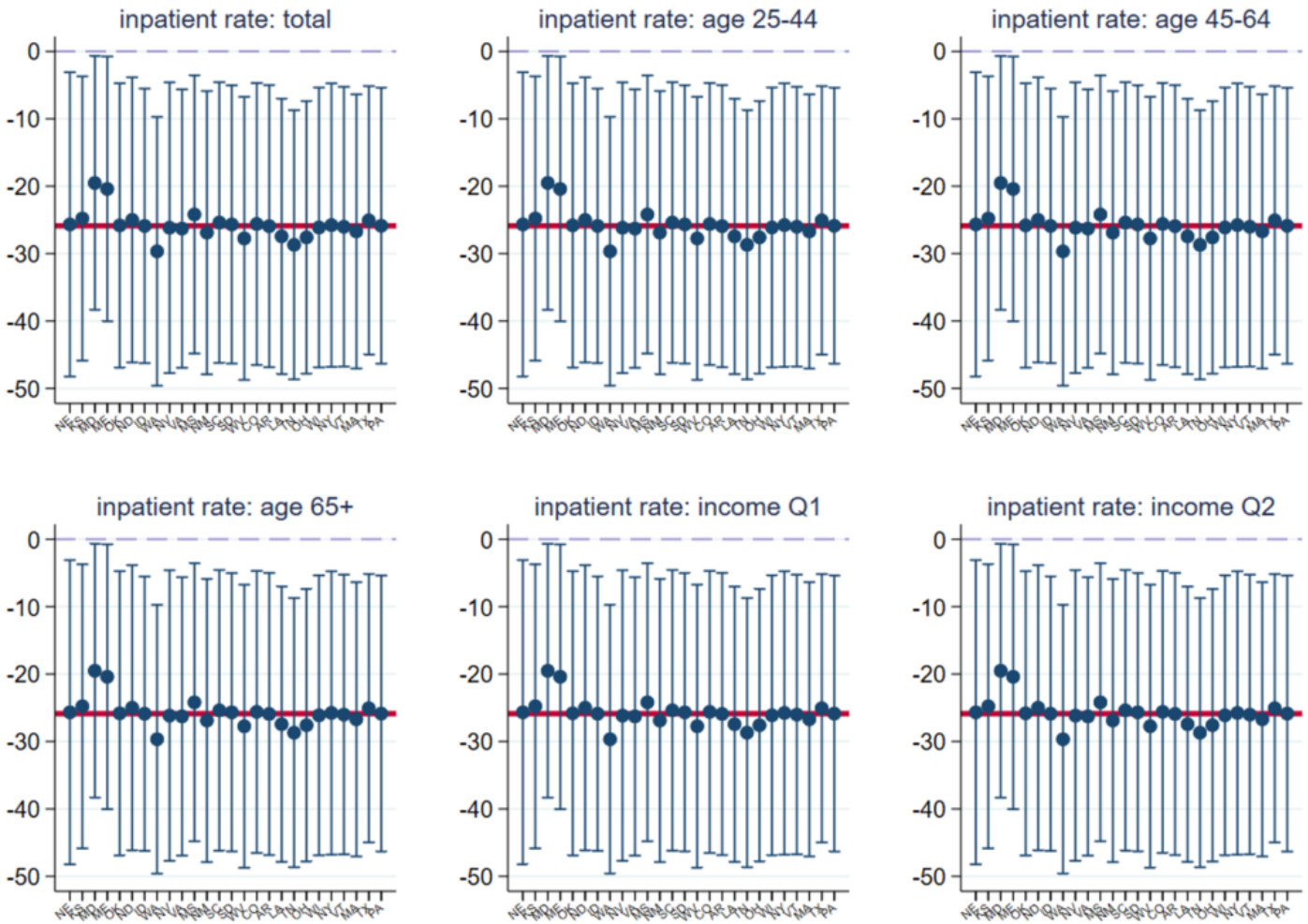
Table A10: opioid-related ER visit (stratified outcomes)

Table A10: Results of Opioid-Related ER Visits, Stratified Outcomes
(unit: *per 100,000 population*)

	ER rate, by age group			ER rate, by income quartile				ER rate, by expected payer		
	25-44	45-64	65+	Q1	Q2	Q3	Q4	Medicare	Medicaid	Private
Panel A: full sample										
PDMP	-58.63*	-3.338	3.520	15.76	-19.53	-16.76	-15.63*	-4.272*	-4.020	-0.808
	(33.60)	(11.63)	(4.805)	(32.49)	(15.17)	(13.07)	(8.066)	(2.511)	(7.227)	(0.842)
mandate	99.70**	17.86	2.093	28.92	29.59	41.34**	13.00**	6.081*	16.80	-0.0582
	(38.21)	(12.42)	(4.639)	(35.73)	(18.57)	(15.26)	(5.698)	(3.452)	(12.55)	(0.929)
integration	35.91	19.28	-2.264	64.34	31.89**	10.71	8.479	1.672	7.975	0.179
	(28.30)	(16.23)	(5.234)	(44.67)	(15.34)	(13.30)	(6.360)	(3.123)	(12.80)	(0.785)
interstate	-14.70	2.281	2.753	10.31	1.133	-11.82	-9.864*	0.572	10.84	-0.783*
	(27.49)	(8.023)	(2.973)	(20.71)	(12.40)	(10.58)	(5.352)	(1.967)	(8.701)	(0.407)
LHS mean	279	149	61	242	174	138	103	37	72	11
N	1,409	1,390	1,214	1,253	1,307	1,292	1,129	1,268	1,242	1,293
Panel B: in subsample of no-mandate states										
integration	20.36	20.98	-6.877	75.38	34.56*	20.41	9.417	0.578	14.93	-0.152
	(22.16)	(17.93)	(4.507)	(46.14)	(18.53)	(12.23)	(6.899)	(3.612)	(13.79)	(0.754)
interstate	6.103	-7.544	-0.894	7.174	-5.132	-7.903	-11.85***	-0.0216	2.019	-0.554
	(13.89)	(9.002)	(3.099)	(17.59)	(6.822)	(4.661)	(3.669)	(1.685)	(6.874)	(0.494)
LHS mean	217	138	64	210	143	111	86	34	63	9
N	789	773	695	692	727	715	594	754	721	769

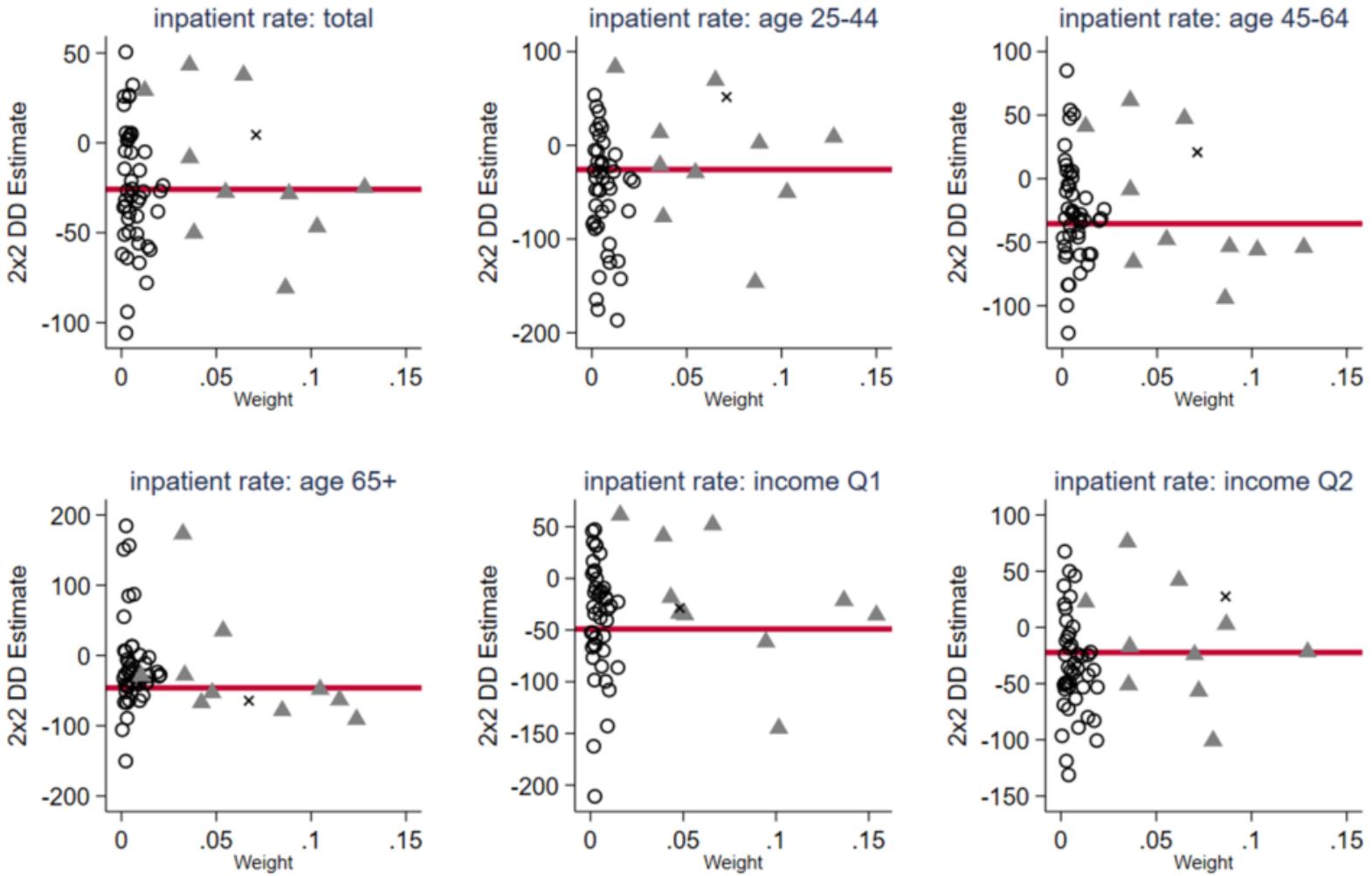
Notes: This table reports the results of estimating the baseline model using equation 1 in full sample and in states never mandated PDMP access during my sample period. In Panel B, only coefficients of interests are reported for simplicity. Each column name represents a dependent variable in a separate regression. Fixed effects for states and year-quarters are always included. Robust standard errors are clustered at the state level and are reported in parentheses. Robust p-values: *** p<0.01, ** p<0.05, * p<0.1.

Fig A1: drop-one-state analysis (sequentially)



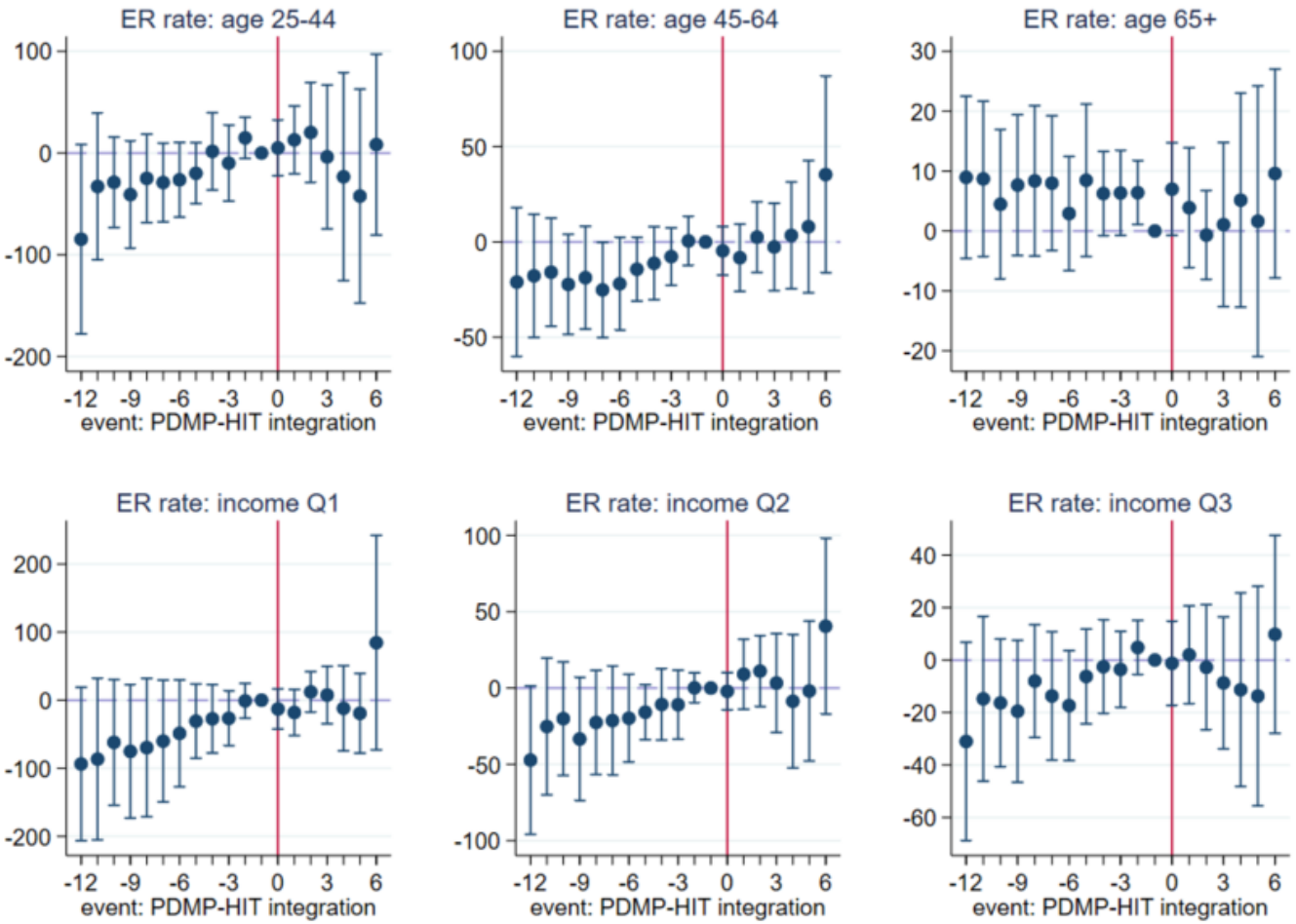
Notes: The figures report the point estimate and 95% CI from the model estimating eqn 1. One treated state is dropped in each regression; the red horizontal line represents the overall estimates. Each estimate drops the state noted on the x-axis (i.e., the 26 states by implementation date): NE KS MD ME OK ND ID WA NV VA MS NM SC SD WV CO AR LA TN OH WI NY VT MA TX PA. (only upper panel is reported here due to space limit)

Fig A2: Bacon decomposition: inpatient outcomes



Notes: The figures report each Bacon decomposed estimate against corresponding weight for the morbidity analysis, corresponding to values reported in Table A7. The red horizontal line represents the two-way fixed effects estimate that equals the average of the y-axis values weighted by their x-axis value. (only upper panel is reported here due to space limit)

Fig A3: event studies for ER visits (stratified)



Notes: These figures report event-study coefficient estimates using Equation 2. Outcome variables are the rates of hospital ER discharge per 100,000 population stratified by adult age group, community-level income quartile, and expected payer. The dots are point estimates of differences in outcome variables between treatment group and control groups 12 quarters before and 6 quarters after implementation. The whiskers correspond to 95% confidence intervals. (only upper panel is reported here due to space limit)