FEATURES OF PRESCRIPTION DRUG MONITORING PROGRAMS AND THEIR RELATIONSHIP TO HOSPITAL UTILIZATION FOR OPIOID-RELATED DIAGNOSES

2005-2013

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Table of Contents

EXECUTIVE SUMMARY

Background

Prescription drug monitoring programs (PDMPs) create state-run databases to monitor prescribing patterns indicative of prescription drug abuse. PDMP features vary by state. There is limited research on their effectiveness, particularly in curtailing utilization of acute care services. This multistate study evaluates the association between four primary PDMP features and emergency department (ED) visits and inpatient hospitalizations for opioid-related diagnoses.

Methods

We used combined ED and hospital inpatient discharge data from 23 states from Healthcare Cost and Utilization Project (HCUP) 2005 through 2013 State Emergency Department Databases (SEDD) and State Inpatient Databases (SID). Our outcome was the rate of combined ED and inpatient discharges associated with opioid-related diagnoses per 100,000 adult population. Principal predictor variables were indicators of four PDMP features—provider-accessible system, proactive alert, interstate data sharing, and mandatory system use—by state year (i.e., each year for a given state). We fit a Poisson regression to estimate the relationship between the expected log (rate) of our outcome of interest and our PDMP characteristic predictor variables. We controlled for state-related fixed effects: state demographic characteristics (percentages of the state population that were covered by Medicaid or Medicare, were of Black race or Hispanic ethnicity, and were unemployed) and the number of per capita alcohol and chemical dependency beds.

Results

The rate of ED visits and inpatient hospitalizations for opioid-related diagnoses per 100,000 population increased overall between 2005 and 2013, but certain PDMP features were associated with slower growth. The provider-accessible system and mandatory system use features of PDMPs were associated with a slower rate of growth over time (–3.9% and –9.3%, respectively) compared with the average rate of growth when study states did not have the PDMP feature. The proactive alert and interstate data-sharing features were not associated with a slower annual rate of growth of opioid-related ED visits and inpatient hospitalizations.

Conclusions

Some PDMP features—in particular, provider-accessible system and mandatory use—were associated with a reduction in the growth rate of ED visits and inpatient hospitalizations for opioid-related diagnoses. More research is needed to understand whether and what kinds of investments in PDMPs produce measurable and meaningful effects.

BACKGROUND

The United States is facing an epidemic of opioid abuse that largely is driven by prescription opioid analgesics. In the past decade, a 300% increase in opioid prescribing has been accompanied by a three-fold increase in the death rate from prescription pain medications [1]. Between 2005 and 2014, emergency department (ED) visits related to opioids nearly doubled, and inpatient hospital stays increased by 64.1 percent [2,3].

The purpose of prescription drug monitoring programs (PDMPs) are to support the legitimate use of prescription drugs, to identify and reduce diversion activities and "doctor-shopping" behaviors (i.e., seeing numerous physicians in an attempt to obtain more prescriptions for controlled substances than would otherwise be permitted), and to help identify individuals with addiction behaviors in order to facilitate treatment [4]. The theory is that by reducing access to prescription opioid drugs and identifying at-risk individuals, PDMPs have the potential to lower opioid abuse and dependence and affect rates of associated ED visits and inpatient hospitalizations [5].

As of 2018, 50 states, the District of Columbia, and the U.S. territories of Guam and Puerto Rico have operational PDMPs [6]. The structure and scope of PDMPs vary considerably [5-9]. Common features that potentially may enhance their effectiveness include the following:

Provider-accessible system: The majority of states have a system of data addressing patients' prior prescription opioid use that is available to providers to query for clinical decision-making. This feature also has been called *provider access* [7,9].

Proactive alert: A number of PDMP systems send providers and law enforcement officials unsolicited reports to alert them about specific individuals with potentially inappropriate or high-risk behavior. This feature also has been called *proactive reporting* and *unsolicited reports* [7,9].

Interstate data sharing: PDMPs share information and access databases across state lines about individuals with potentially inappropriate or high-risk opioid use. This feature is intended to assist providers and law enforcement entities in detecting doctor-shopping behaviors in neighboring states [7,9].

Mandatory system use: Although use of PDMPs by prescribers is voluntary in most cases, some states require providers to query PDMP systems before prescribing opioids for any patient. Other states require providers to access PDMPs in specific circumstances, such as for special populations (e.g., clients of pain clinics or opioid treatment clinics), for cases involving a high suspicion of abuse, or for certain high-potency opioids [7,9].

The Centers for Disease Control and Prevention and the Brandeis PDMP Center of Excellence have noted that the provider-accessible system, proactive alert, and interstate data-sharing features are among the best practices for a strong PDMP [7,8]. Other features such as mandatory system use also are promising, although they have less empirical evidence [7,9].

Most existing studies, which have been limited to opioid-related deaths and overdoses as primary outcomes, have shown mixed results on whether PDMPs reduce adverse events related to opioids [3,10-16]. Some features of PDMPs, such as more aggressive monitoring of a larger variety of drug schedules, more frequent reporting, and mandatory enrollment and access, were associated with lower rates of misuse and deaths from opioid overdoses in some states [10,14,15]. Other studies evaluating the role of PDMPs have focused on provider

behaviors as outcomes [17-24]. However, there is scant evidence about the effects of particular features of PDMPs on opioid-related use of acute health care services, such as ED visits and inpatient hospitalizations [25,26].

METHODS

Study Aim

The aim of this study was to evaluate the association between state PDMP features and acute hospital service utilization for opioid-related diagnoses using ED and inpatient discharge data. We hypothesized that use of four primary PDMP features each would be associated with a decrease in the trend of opioid-related acute care utilization.

Study Setting and Population

This was a retrospective cohort study using Agency for Healthcare Research and Quality (AHRQ) Healthcare Cost and Utilization Project (HCUP) data. We used combined ED and hospital inpatient discharge data from the HCUP 2005 through 2013 State Emergency Department Databases (SEDD) and State Inpatient Databases (SID). HCUP is a family of administrative databases of all-payer, encounter-level ED and hospital discharge records from participating states [27]. We included 23 states that had both SEDD and SID data available during our study period: Arizona, California, Connecticut, Florida, Georgia, Hawaii, Indiana, Iowa, Kansas, Maryland, Massachusetts, Minnesota, Missouri, Nebraska, New Jersey, New York, Ohio, South Carolina, South Dakota, Tennessee, Utah, Vermont, and Wisconsin [28]. A total of 22 states had data available from 2005 through 2013 and one state had data available from 2005 through 2012. We focused on the subset of ED and inpatient discharges for adults aged 18 years and older from general medical and surgical, community, and nonrehabilitative hospitals. We included ED discharges (ED visits for which the patient was not admitted to the same hospital) and inpatient stays (ED visits for which the patient was admitted to the same hospital and all other types of admissions). To eliminate duplicative records for transfer cases, we included the records that had a “transfer to” disposition but excluded other admission records with a “transfer from” source.

Study Protocol

Our principal predictor variables were indicators of four PDMP features—provider-accessible system, proactive alert, interstate data sharing, and mandatory system use—by state year (i.e., each year for a given state). We obtained data for these PDMP features from the National Alliance for Model State Drug Laws [9].

We characterized a state as having mandatory system use only if that state required provider PDMP use for all opioid prescriptions, rather than relying on suspicion of use or limiting use to certain subpopulations or certain classes of opioids [7,9]. Our assumption was that PDMP features did not become immediately effective on enactment, but instead required implementation and a “learning period” during which uptake grows. We therefore also included variables to denote the number of years each feature had been in effect [7,9].

We included state-related fixed intercepts to control for the initial rate variation across states, using publicly available data to capture the covariates that could affect our analysis. We controlled for the percentage of the population by state who self-reported nonmedical use of pain relievers, extracted from the Substance Abuse and Mental Health Services Administration

National Survey on Drug Use and Health. We also examined a number of other covariates identified in prior studies that could influence our outcome and included in our final models those that varied within states over time [29]. These variables included Claritas intracensal demographic data (i.e., percentages of the state population that were of Black race or Hispanic ethnicity, and were male) and the United States Census Bureau American Community Survey (i.e., percentages of the state population that were covered by Medicaid or Medicare, and were unemployed) for each state year, as well as state-specific access to substance abuse treatment measured by the number of alcohol and chemical dependency treatment beds per capita from the American Hospital Association [30-33].

Key Outcome Measures

Our outcome of interest was the rate of combined ED and inpatient discharges associated with opioid-related diagnoses per 100,000 adult population—an indirect measure of the incidence of opioid abuse within populations. Opioid-related diagnoses were defined as ED and inpatient discharges with a first-listed diagnosis using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis codes for dependence (304.00–304.02, 304.70–304.72), abuse (305.50–305.52), or poisoning (965.00, 965.09), as well as discharges with any associated external cause of injury codes (E codes) for accidental poisoning by other opiates or narcotics (E850.2) [34]. ICD-9-CM diagnosis codes related to heroin dependence or abuse were not used to identify opioid-related hospital discharges. Although the use of illicit opioids is of growing concern, especially in association with addiction to prescription opioids, we did not include discharges with heroin codes (poisoning by heroin 965.01, accidental poisoning by heroin E850.0, heroin causing adverse effects in therapeutic use E935.0) because PDMPs do not directly target illicit opioids, and the number of discharges with these specific codes in our sample was small (1.5% of all discharges in each state-year, on average).

Data Analysis

We first evaluated trends over time by state for our outcome and for each of our predictor variables. The average annual rate of combined ED visits and inpatient hospitalizations for opioid-related diagnoses was plotted for states in relationship to year of PDMP feature enactment. We found that state-specific trends tended to be linear in the log (rate) both before and after implementation of each of the four features.

Next, because visits for opioid-related diagnoses were relatively rare, we used a Poisson generalized estimating equation model with an offset of our denominator (state population), assuming first-order autoregressive correlation over time within each state. The Poisson regression estimated the relationship between the expected log (rate) and our predictor variables. Consequently, the antilogarithm of each regression coefficient estimated the *multiplicative* impact of a one-unit increase in the corresponding predictor. This method allowed us to address the estimated effect of each predictor in terms of a percentage change in the rate. We performed sensitivity analyses, described below, before fitting our final model.

Using this methodology, we modeled a total of three regressions to examine our outcome of interest. In Model 1, we estimated the differences between states with and without a feature and the effects of PDMP features after enactment over time, controlling for state-specific effects and self-reported rates of nonmedical use of pain relievers. In Model 2, we added a control for state per capita alcohol and chemical dependency beds. Model 3 was our fully adjusted model, which included all variables from Model 2 with added controls for the percentage of the state

population with selected demographic characteristics. In each model, when statistically significant, the coefficients for the PDMP features were fairly robust, even when controlling for other tested confounders. Our results focus on Model 3, the fully adjusted model, but we have included data from our other Models (1 and 2) in the additional files (see Table A.1 in Appendix A).

We performed sensitivity analyses to test each PDMP feature individually and in concert. We examined interaction terms between our PDMP predictors, which were not found to be significant. We also tested the exclusion of states with PDMP features in effect for a substantial period of time preceding our study period (2005), but the results were unaltered. Our final model therefore included all states to increase the statistical power of the analysis.

We also considered a number of other potential demographic predictors that could potentially affect our outcome. We included only those predictors that had large variation in yearly changes by state. State-related fixed effects accounted for unmeasured differences among states. We also examined our demographic and PDMP predictors for collinearity. All data were analyzed using SAS version 9.4.

RESULTS

Sample Characteristics

Our final sample consisted of 205 state-year observations from 23 states. On average during the observed time period, 41.5% of observations were ED discharges; 42.1% were inpatient stays originating with an ED visit, and 16.4% were inpatient stays from other types of admissions.

From 2005 through 2013, there was an increase in the number of states that had enacted the four PDMP features (Table 1). The numbers rose from 4 to 19 for the provider-accessible system feature, from 3 to 16 for the proactive alert feature, from 0 to 15 for the interstate data-sharing feature, and from 0 to 4 for the mandatory system use feature. In the 6 states that had at least one PDMP feature as of 2005, the average total number of ED visits and inpatient hospitalizations for opioid-related diagnoses was 255.9 per 100,000 adult population. By 2013, this number increased to 360.8 per 100,000 adult population. In the 17 states without PDMPs enacted as of 2005, the average total number of opioid-related ED visits and inpatient hospitalizations was 210.7 per 100,000 adult population; this number increased to 251.7 per 100,000 in 2013.

Table 1. PDMP Characteristics, Substance Abuse Treatment Access, State Demographics, and Rate of Opioid-Related Discharges, by Year

Characteristic	2005	2006	2007	2008	2009	2010	2011	2012	2013
States with a PDMP,[a] n	6	11	13	15	16	19	21	21	20
States with a provider-accessible system, n	4	5	6	9	12	14	16	18	19
States with proactive alert, n	3	5	6	8	9	15	16	17	16
States with interstate data sharing, n	0	3	4	6	6	11	13	15	15
States with mandatory system use, n	0	0	0	0	0	0	1	2	4
Nonmedical use of pain relievers, mean % (SD)	15.5 (2.68)	16.6 (2.72)	16.0 (3.04)	15.2 (2.85)	15.2 (1.9)	14.7 (2.03)	13.6 (2.1)	13.2 (1.79)	12.5 (1.63)
Alcohol/chemical dependence beds per 100,000 pop, n (SD)	1.6 (1.85)	1.2 (1.45)	1.2 (1.56)	1.1 (1.44)	1.0 (1.49)	1.0 (1.45)	1.0 (1.42)	0.9 (1.39)	0.9 (1.29)
Medicaid, mean % (SD)	14.1 (3.34)	13.8 (3.18)	13.8 (3.27)	14.1 (3.84)	15.1 (4.04)	15.6 (3.45)	16.4 (3.52)	16.4 (3.98)	17.2 (3.08)
Medicare, mean % (SD)	13.3 (2.32)	14.3 (2.01)	14.3 (1.9)	14.6 (1.83)	15.0 (1.95)	15.3 (1.82)	15.4 (1.93)	15.6 (1.87)	16.1 (1.95)
Unemployed, mean % (SD)	4.8 (1.16)	4.4 (1.15)	4.4 (0.97)	5.4 (1.15)	8.9 (1.68)	8.8 (1.94)	8.0 (1.82)	7.2 (1.7)	6.6 (1.58)
Black, mean % (SD)	8.7 (6.62)	9.2 (8.59)	8.4 (8.07)	8.5 (7.52)	9.0 (7.29)	8.2 (6.86)	10.2 (8.98)	10.4 (9.16)	10.6 (9.35)
Hispanic, mean % (SD)	12.4 (12.35)	9.0 (9.88)	10.4 (10.84)	10.8 (10.33)	11.7 (10.3)	11.0 (9.82)	11.0 (9.44)	11.7 (9.48)	12.1 (9.81)
Total ED visits and inpatient discharges per 100,000 population, n (SD)[a]	255.9 (147.84)	237.9 (141.64)	233.6 (114.22)	256.5 (120.19)	278.0 (122.00)	290.9 (132.66)	334.7 (167.54)	359.6 (179.84)	360.8 (170.84)
States with no PDMP,[b] n	17	12	10	8	7	4	2	2	2
Nonmedical use of pain relievers, mean % (SD)	14.5 (2.36)	15.2 (2.12)	14.8 (2.65)	14.5 (3.18)	14.4 (2.25)	13.9 (2.05)	13.8 (1.97)	13.0 (1.58)	12.6 (2.78)
Alcohol/chemical dependence beds per 100,000 pop, n (SD)	1.2 (1.00)	1.2 (1.1)	1.0 (0.94)	1.0 (0.94)	1.0 (0.9)	1.3 (1.04)	1.5 (1.88)	0.7 (0.67)	1.2 (1.67)
Medicaid, mean % (SD)	12.0 (2.94)	11.2 (2.31)	11.4 (2.89)	12.9 (2.06)	14.3 (3.53)	12.7 (1.5)	13.2 (2.62)	11.8 (1.77)	13.9 (1.27)
Medicare, mean % (SD)	14.6 (1.46)	14.4 (1.6)	14.8 (1.66)	15.0 (1.83)	14.9 (1.7)	14.3 (1.93)	16.1 (0.92)	16.2 (1.2)	16.6 (1.34)

Characteristic	2005	2006	2007	2008	2009	2010	2011	2012	2013
Unemployed, mean % (SD)	4.6 (0.81)	4.1 (0.67)	4.1 (0.74)	4.9 (1.29)	7.6 (1.98)	8.0 (2.41)	6.5 (2.83)	5.5 (2.12)	5.2 (1.84)
Black, mean % (SD)	10.2 (9.61)	10.4 (9.55)	11.9 (9.98)	12.6 (11.04)	12.3 (11.85)	18.3 (12.53)	7.8 (4.88)	8.0 (4.98)	8.1 (5.03)
Hispanic, mean % (SD)	7.6 (7.27)	9.4 (7.95)	8.3 (5.58)	7.6 (5.76)	5.9 (2.43)	6.6 (2.31)	6.1 (3.63)	6.8 (4.24)	7.0 (4.36)
Total ED visits and inpatient discharges per 100,000 population, n (SD)[c]	210.7 (179.97)	226.9 (195.16)	240.2 (197.82)	255.8 (215.32)	287.2 (245.96)	320.7 (263.15)	232.8 (169.35)	245.7 (183.84)	251.7 (180.94)

Abbreviations: ED, emergency department; PDMP, Prescription Drug Monitoring Program; pop, population; SD, standard deviation.

[a] States with a Prescription Drug Monitoring Program for all or part of the reference year. Includes only states with data on outcome variable for that year. For 2013, one state with a PDMP had no outcome data.

[b] States without a Prescription Drug Monitoring Program for the entire reference year.

[c] Emergency department visits and inpatient discharges are for opioid-related diagnoses per adult (18+ years) 100,000 population.

Data sources were the Healthcare Cost and Utilization Project (HCUP) State Emergency Department Databases (SEDD) and State Inpatient Databases (SID), National Alliance for Model State Drug Laws, the Substance Abuse and Mental Health Services Administration National Survey on Drug Use and Health, U.S. Census Bureau American Community Survey, American Hospital Association [7,9,30,31,32,33].

Trend in Rates of ED Discharges and Inpatient Hospitalizations

We graphed the trend in rates of ED discharges and inpatient hospitalizations for opioid-related diagnoses by each PDMP feature for each of the 23 states in our sample, coded to indicate time before and after enactment of the feature. Prior to enactment of the provider-accessible system feature, states had varying levels and rates of increase in ED visits and inpatient hospitalizations for opioid-related diagnoses. After enactment, some states had a smaller increase in the rates when compared with the preceding period, whereas others had no change or slight increases in the rates. Please see Additional File 1 (Figures A.1–A.4 in Appendix A for the provider-accessible system, proactive alert, interstate data sharing, and mandatory system use features, respectively) for state-level trends in actual rates of ED discharges and inpatient hospitalizations relative to the enactment of the features.

Association Between PDMP Features and Opioid-Related ED Discharges and Hospitalizations

Table 2 summarizes the estimated differences between the states with and without a PDMP feature (the intercept) and the effects of each feature on the average rate of change estimated for that feature (the slope), derived on the basis of the coefficients estimated for the fully adjusted model. On average, the presence of the proactive alert feature in a state was associated with a 7.4% lower rate of ED visits and inpatient hospitalizations for opioid-related diagnoses than in the no-PDMP baseline period ($p < .05$). The other three PDMP features (provider-accessible system, interstate data sharing, and mandatory system use) were not significantly associated with the baseline rate of ED visits and inpatient hospitalizations for opioid-related diagnoses.

Table 2. Effect of PDMP Features on Intercept and Slope of Rate Trends, in Percentages[a]

Feature	Estimated intercept effects
Provider-accessible system	–2.8
Proactive alert	–7.4*
Interstate data sharing	0.1
Mandatory system use	0.1
	Estimated slope effects
No PDMP features (baseline slope)	4.4
Provider-accessible system[b]	–3.9*
Proactive alert[b]	3.8**
Interstate data sharing[b]	1.2
Mandatory system use[b]	–9.3**

Abbreviations: PDMP, Prescription Drug Monitoring Program.

Table S.1 contains coefficients used to calculate rates and annual change figures.

[a] Rates are emergency department visits and inpatient hospitalizations for opioid-related diagnoses per 100,000 adult population.

[b] Change represents years since enactment.

*$p < .05$. **$p < .01$.

Data sources were the Healthcare Cost and Utilization Project (HCUP) State Emergency Department Databases (SEDD) and State Inpatient Databases (SID), National Alliance for Model State Drug Laws [9,28].

Association Between Years Since Enactment of PDMP Features and Opioid-Related ED Discharges and Hospitalizations

There was a significant association between our outcome and the years since enactment of the provider-accessible system, proactive alert, and mandatory system use features (Table 2). State-years that lacked all PDMP features averaged a 4.4% annual increase in the rate of ED visits and inpatient hospitalizations for opioid-related diagnoses, controlling for other predictors.

Enactment of the provider-accessible system feature was associated with an estimated 3.9% decrease in the annual rate of change, on average, for the trend in ED visits and inpatient hospitalizations per population for opioid-related diagnoses ($p < .05$). Consequently, after states enacted the provider-accessible system feature, this average utilization per population increased only 0.5% per year (the 4.4% baseline rate in state-years with no PDMP features minus the 3.9% effect of the provider-accessible system feature).

The mandatory system use feature was associated with a 9.3% decrease in the annual rate of growth in ED visits and inpatient hospitalizations per population for opioid-related diagnoses ($p < .01$). Therefore, a state with the mandatory system use feature actually had an average decline of 4.9% per year (the 4.4% baseline rate in states with no PDMP features minus the 9.3% effect of the mandatory system use feature).

The proactive alert feature, however, was associated with an average estimated 3.8% increase in the annual growth of the rate of ED visits and inpatient hospitalizations for opioid-related diagnoses compared with having no PDMP in place ($p < .01$). A state with the PDMP proactive alert feature had an estimated average increase of 8.2% per year. There was no significant association between our outcome and the time since enactment of the interstate data-sharing feature.

DISCUSSION

The coefficients in our study that represented the time since enactment of the provider-accessible system and mandatory system use features were statistically significant and of a relevant magnitude. Prior studies evaluating the association between PDMPs and acute care utilization for opioids have shown varied outcomes [25,26]. One study of 11 metropolitan areas using the Drug Abuse Warning Network found increasing rates of ED visits for opioid-related diagnoses from 2004 to 2011; however, there was no difference in ED visit rates associated with the implementation of a provider-accessible PDMP [25]. Our results are consistent with those from another multistate study that also showed a slower rate of increase of opioid-related ED visits and inpatient hospitalizations in states with PDMPs with the provider-accessible system feature. Compared with the current study, the earlier study had a more narrow focus only on opioid poisoning among privately insured adults [26].

Upon enactment of the provider-accessible system feature, providers initially may not be motivated to use PDMP databases because of lack of familiarity, barriers to accessing these databases (e.g., need for registration to gain access to the database and time required to check the data), or absence of suspicion of abuse in a single visit with a patient (as in an ED visit) [35,36]. As providers become more familiar with a PDMP system and how it applies to relevant patients, they may use the system more frequently; over time, this increased use may result in a reduction in use of hospital services for opioid-related diagnoses. The mandatory system use feature in particular may take time to implement fully, depending on such aspects as the state's willingness and ability to enforce mandatory use of the PDMP [37].

Although enactment of the proactive alert feature was associated with lower initial outcome rates, the time since enactment had a surprising, positive association with the annual rate of change in ED visits and inpatient hospitalizations per population for opioid-related diagnoses. State implementation of the proactive alert feature requires a large amount of resources, and states release reports at varying intervals [38-40]. Although proactive PDMPs may be helpful for providers who follow patients on a regular basis, depending on the timing of their reports, the PDMPs may be less useful in curtailing activity in some clinical settings. For example, an ED provider may receive a proactive alert about suspicious opioid use weeks after a referenced visit [35].

Our research has a number of important policy implications. Although individual PDMP features may not be sufficient to alter rates of opioid use immediately upon enactment, such features may be effective in slowing the annual increase in ED visits and inpatient hospitalizations for opioid-related diagnoses over time.

Our data demonstrated that the mandatory system use feature may have an effect in reducing ED visits and inpatient hospitalizations for opioid-related adverse events; however, our data had a limited number of states that had enacted this feature during our analysis period, which restricts the implications that can be made from these findings. Providers in states that have implemented mandatory system use were more likely to access the PDMP system and to have decreased rates of opioid prescribing [15,40]. Mandatory system use has been associated with lower numbers of deaths from opioids and lower numbers of opioid prescriptions dispensed in states that have this feature [10,15]. As of 2018, 42 states have some type of mandate in place requiring physicians to use PDMPs, although the circumstances in which such requirements occur varies [40]. Twenty-five states require use of PDMPs by all providers prior to prescribing opioids to a patient at least for the first time [41].

A major barrier to PDMP effectiveness has been the relatively low rates of use by providers because of administrative burdens, need for information technology and other staff support, or other concerns [37,42-45]. Studies have shown that clinicians use PDMPs infrequently, often only in cases of high clinical suspicion and with varying impact on prescribing practices [16-25]. A multidisciplinary survey of Oregon providers showed that pain management, primary care, and emergency medicine providers were the most likely to be registered with PDMPs, but only 4% of all users accessed the PDMP for every patient [22].

Accessing PDMPs for patient-related queries requires additional time that may increase provider workload [43-45]. In a study of the usability of the Massachusetts's PDMP, the time to access PDMPs was substantially longer and involved more computer steps (mouse clicks) compared with other common tasks performed in the ED [45]. Mandatory system use may raise PDMP use by forcing providers to overcome these barriers; however, this feature may be viewed as potentially interfering with independent clinical decision-making [5,37,46]. States that have been successful with a PDMP mandatory system use have increased PDMP staff support at the time of implementation to ease the provider enrollment process and have included educational campaigns about the utility of PDMPs [5,47]. It also is possible that provider use would be increased if PDMPs were very user-friendly, provided the most recent information, and could be integrated easily into other electronic medical record systems [5,42,48].

Even when used by providers, PDMPs may have varying effects on behavior [17-19]. A single center study in Florida before and after implementation of the state's PDMP demonstrated no difference in the mean number of opioids prescribed when information about a patient's use of

opioids was made available to providers [18]. Other factors may impede providers' decisions to prescribe opioids regardless of information provided by PDMPs, such as patient satisfaction concerns [20,21,23,45]. Ethical issues also may exist with the use of PDMPs in the acute care setting, where little is known about a patient's prior history, including the concern that use may impede appropriate prescribing of opioids when needed [47,48].

The measures we analyzed—trends in ED visits and inpatient hospitalizations—reflect somewhat indirect measures of the effects of PDMPs. Additional outcomes that measure changes in behaviors that PDMPs aim to affect (e.g., provider opioid prescribing patterns, patients' doctor shopping) would help pinpoint the impacts of these programs. PDMPs have been shown to reduce provider prescribing of Schedule II opioids and to curtail opioid prescribing by high- volume prescribers, but evidence of their impact on other types of opioids and among other providers is limited [49-52]. Other goals of PDMPs, such as controlling doctor shopping, are difficult to quantify and have not been studied extensively [5]. Definitions of "inappropriate" use of multiple doctors vary across patients, providers, or even states, and thus no consistent threshold for doctor shopping currently exists [4].

Limitations

Our small sample size of 205 state-years may have limited our ability to detect meaningful outcomes. Because outcome data were available only from 2005 through 2013, we had limited data for some states on rates before or after enactment of PDMP features, especially for the mandatory use feature. In addition, we lacked information on other factors that might or have been shown to affect the outcomes. Examples include pharmaceutical data on the annual number of opioids distributed by state in order to control for geographic variations in provider prescribing practices, [52,53] and state-level data about supplies of prescription opioids obtained from illicit sources, such as through illegal online pharmacies and other sources of drug trafficking that may have increased the number of opioid-related ED visits and inpatient hospitalizations [54].

Visits related to opioid abuse and dependence tend to be undercoded in administrative data; therefore, we may have missed visits for opioid-related diagnoses not captured with the diagnosis codes we used [55]. We also did not include other types of diagnoses—such as pain-related syndromes, infections, hepatitis, or human immunodeficiency virus—that may have been associated with opioid use. While some cases of opioid-related ED visits and hospitalizations might have been missed by omitting these types of diagnoses, the restriction resulted in a more targeted study.

Although our model featured separate state intercepts, we were not able to include potentially relevant covariates for state-specific policies, such as pain clinic regulation laws in some states, Medicaid utilization review laws, state demonstration and community-based programs that address opioid use, or the triplicate form requirement for opioid prescribing (a three-copy prescription form with copies going to the physician, pharmacist, and state regulating agency, aimed at deterring potential prescription forgery) [3,56,57]. However, these policies affected very few of the states and only limited subpopulations within our sample; therefore, separate state intercepts likely were sufficient.

CONCLUSIONS

Our data show that some PDMP features may be associated with a reduction in the growth rate of ED visits and inpatient hospitalizations for opioid-related diagnoses; however, the effects

shown in our study were relatively small or were based on limited observations for certain PDMP features. Despite the increased implementation of PDMPs over the last decade, rates of opioid abuse have continued to rise.

Significant resources are required to implement PDMPs, including the addition of features that enhance provider use, such as easier enrollment processes [5,38]. More research is needed to understand whether and what kinds of investments in such programs produce measurable, positive outcomes. Programs become established with considerable variability in design, operations, scrutiny, and enhancements, even within the features of the programs studied here.

Additional information also is needed on whether operational characteristics of PDMPs, such as reporting periods, ease of enrollment, or linkage to electronic medical records, affect provider willingness to use the systems [5]. Future evaluations should examine whether there is a quantifiable link between the frequency of inquiries made by providers, opioid prescribing practices, and adverse outcomes related to prescription opioids [5,38].

Finally, we need to understand how other policy strategies work with PDMPs, such as other approaches implemented by state Medicaid agencies to curtail opioid use. Many states have drug utilization review policies that evaluate cases of Medicaid beneficiaries with high opioid use [3,58]. Such reviews may identify patients who need ancillary services, such as referral to pain management clinics, or may trigger the implementation of quantity limits or prior authorization to help restrict potential misuse. Further research is needed on whether such approaches support or dilute the impact of PDMPs [58]. PDMPs represent one of many strategies for reducing opioid addiction rates of epidemic proportion. Although research is hampered by the considerable variation that exists across these programs, it is important that we develop a better understanding of program features that could increase their effectiveness.

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APPENDIX A

Table A.1 contains detailed results from the three regression models. States with a higher percentage of individuals reporting nonmedical use of pain relievers had a lower rate of emergency department (ED) visits and inpatient hospitalizations for opioid-related diagnoses ($p < .01$). States with a higher percentage of individuals with Hispanic ethnicity had lower rates of ED visits and inpatient hospitalizations for opioid-related diagnoses ($p < .05$) but higher rates of unemployment ($p < .01$). Although numbers of per capita alcohol and chemical dependency beds by state were associated with lower rates of opioid-related diagnoses in Model 2, this result was no longer significant when demographic factors were controlled. Other demographic coefficients (percentage Black, Medicaid, or Medicare by state) were not significant.

The reason for the association between higher rates of self-reported, nonmedical pain reliever use and lower rates of ED visits and inpatient hospitalizations for opioid-related diagnoses is unclear. Perhaps individuals using nonmedical pain relievers take opioids at thresholds below that which would result in adverse events. Alternatively, they may have more experience with opioid-related adverse events and therefore require fewer ED visits or inpatient hospitalizations for such occurrences. This measure also may be correlated with other outcomes associated with prescription opioid use that not captured in our data. For example, patients who seek prescription opioids in the acute care setting often present with pain-related complaints that may not be recognized as abuse or dependence [35]. Furthermore, the National Survey on Drug Use and Health survey measures a cross-sectional sample of groups about the nonmedical use of pain relievers; it is not a direct measure of opioid use [30].

Figures A.1–A.4 show state rates of opioid-related diagnoses before and after enactment of the provider-accessible system, proactive alert, interstate data sharing, and mandatory use features of prescription drug monitoring programs (PDMPs). Individual states had wide variations in opioid-related discharges before and after enactment of these features. As noted in the main body of the paper, more research is needed to understand whether and what kinds of investments in PDMPs produce measurable, positive outcomes.

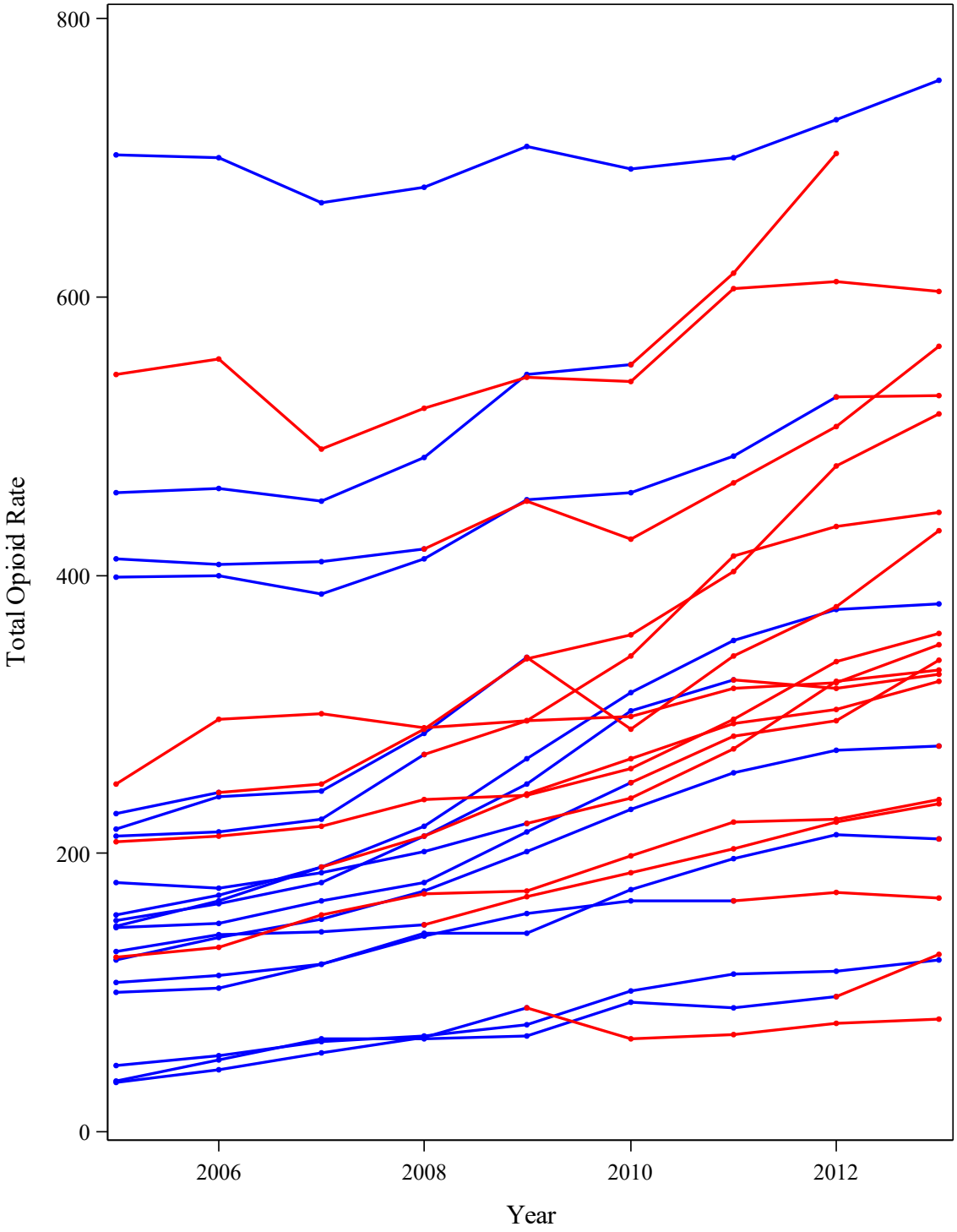
Table A.1. Regression Coefficients for Opioid-Related Emergency Department and Hospital Visits per 100,000 Adults, 2005–2013[a]

Parameter	Model 1	Model 2	Model 3
Years since 2005	0.0523	0.0487	0.0432
State nonprescription opioid use rate	–0.0225**	–0.0214**	–0.0233**
Provider-accessible system	–0.0101	–0.0128	–0.0280
Proactive alert	–0.0819*	–0.0848*	–0.0764*
Interstate data sharing	–0.0173	–0.0030	0.0011
Mandatory system use	0.0042	–0.0211	0.0012
Provider-accessible system years since enactment	–0.0523**	–0.0444*	–0.0396*
Proactive alert years since enactment	0.0282	0.0238	0.0372**
Interstate data sharing years since enactment	0.0088	0.0096	0.0122
Mandatory system use years since enactment	–0.0851**	–0.0844**	–0.0973**
Per capita rate of alcohol and chemical dependence beds		–0.0399*	–0.0449
Percent Medicaid			0.0037
Percent Medicare			–0.0071
Percent Unemployed			0.0198**
Percent Black			0.0492
Percent Hispanic			0.0467*

*p < .05. **p < .01.

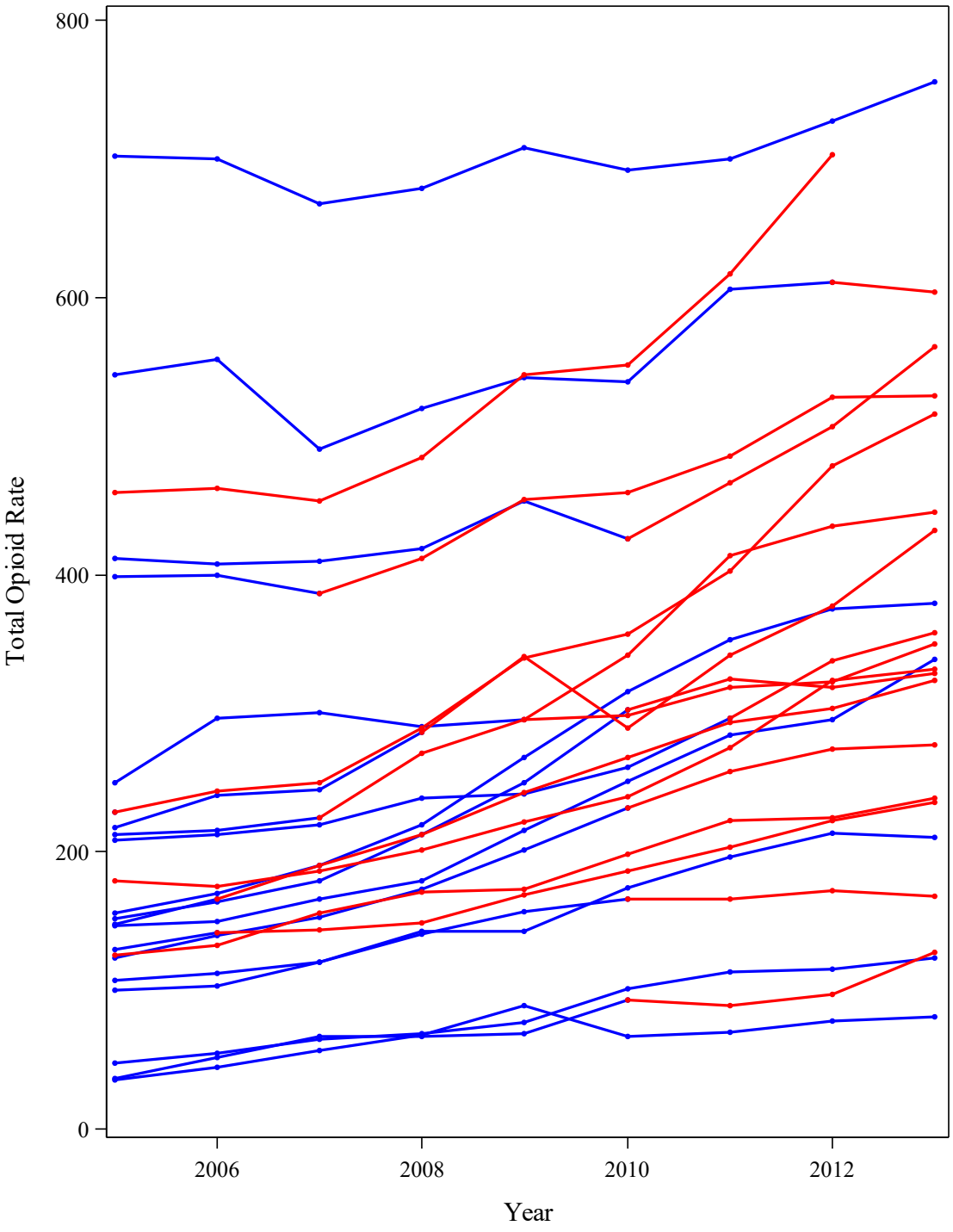
Data sources were the Healthcare Cost and Utilization Project State Emergency Department Databases and State Inpatient Databases, National Alliance for Model State Drug Laws, Substance Abuse and Mental Health Services Administration National Survey on Drug Use and Health, U.S. Census Bureau American Community Survey, American Hospital Association [7,9,30,31,32,33].

Figure A.1. Trend in opioid-related discharge rates by state relative to enactment of the provider-accessible system feature[a]



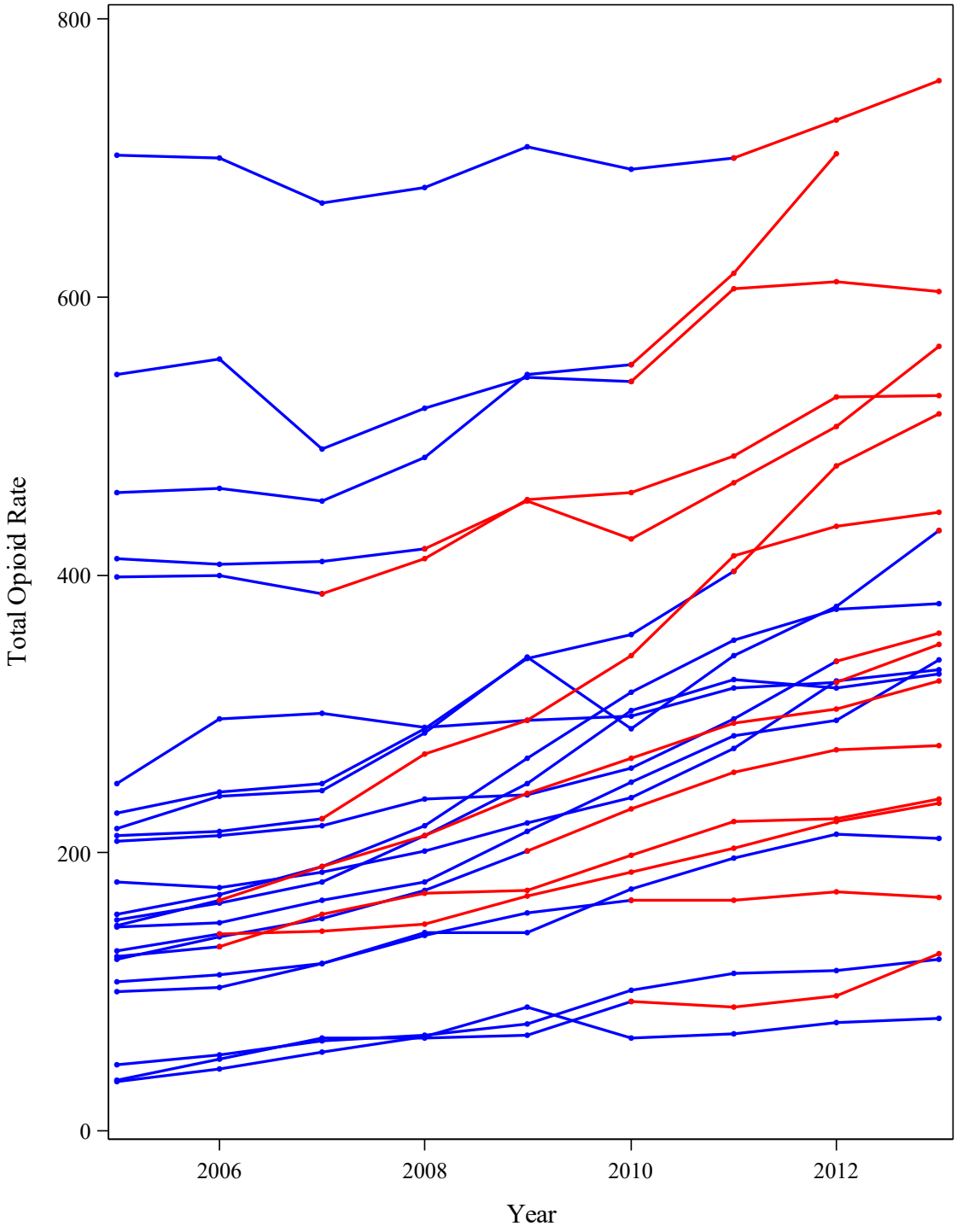
[a] Each line represents a state's trend in total (emergency department and inpatient) opioid-related discharge rate. Blue line indicates period prior to enactment of the provider-accessible system feature for prescription drug monitoring program; red line indicates period after enactment of the provider-accessible system feature for prescription drug monitoring program. Data sources were the Healthcare Cost and Utilization Project (HCUP) State Emergency Department Databases (SEDD) and State Inpatient Databases (SID), National Alliance for Model State Drug Laws [9, 28].

Figure A.2. Trend in opioid-related discharge rates by state relative to enactment of the proactive alert feature[a]



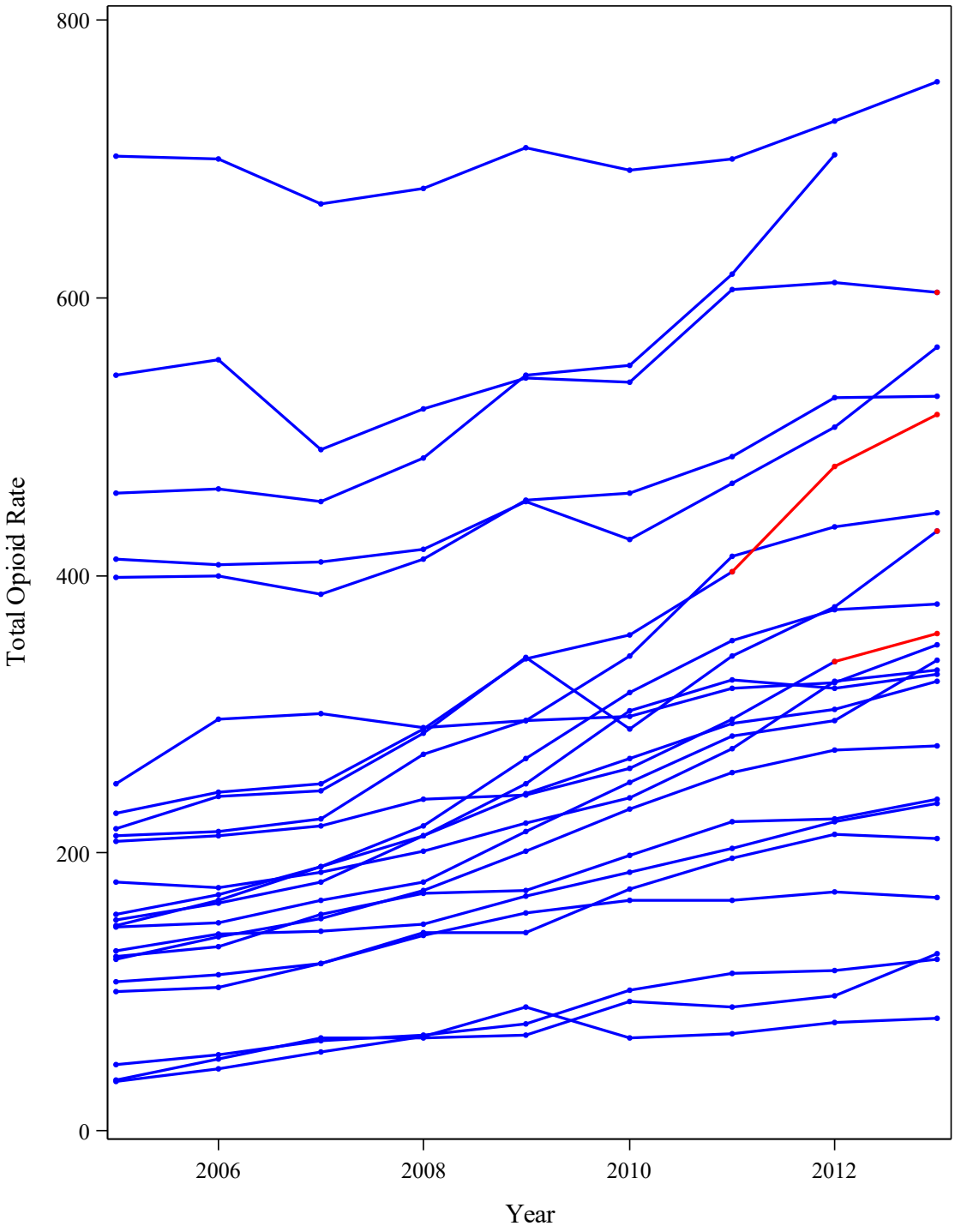
[a] Each line represents a state's trend in total (emergency department and inpatient) opioid-related discharge rate. Blue line indicates period prior to enactment of the proactive alert feature for prescription drug monitoring program; red line indicates period after enactment of the proactive alert feature for prescription drug monitoring program. Data sources are the Healthcare Cost and Utilization Project (HCUP) State Emergency Department Databases (SEDD) and State Inpatient Databases (SID), National Alliance for Model State Drug Laws [9,28].

Figure A.3. Trend in opioid-related discharge rates by state relative to enactment of the interstate data-sharing feature[a]



[a] Each line represents a state's trend in total (emergency department and inpatient) opioid-related discharge rate Blue line indicates period prior to enactment of the interstate data-sharing feature for prescription drug monitoring program; red line indicates period after enactment of the interstate data-sharing feature for prescription drug monitoring program. Data sources are the Healthcare Cost and Utilization Project (HCUP) State Emergency Department Databases (SEDD) and State Inpatient Databases (SID), National Alliance for Model State Drug Laws [9,28].

Figure A.4. Trend in opioid-related discharge rates by state relative to enactment of the mandatory system use feature[a]



[a] Each line represents a state's trend in total (emergency department and inpatient) opioid-related discharge rate. Blue line indicates period prior to enactment of the mandatory system use feature for prescription drug monitoring program; red line indicates period after enactment of the mandatory system use feature for prescription drug monitoring program. Data sources are the Healthcare Cost and Utilization Project (HCUP) State Emergency Department Databases (SEDD) and State Inpatient Databases (SID), National Alliance for Model State Drug Laws [9,28].