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The Problem of Data Quality in Analyses of Opioid Regulation: The Case of Prescription Drug Monitoring Programs

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ABSTRACT

States, which have the primary legal role in regulating the prescribing and dispensing of prescription medications, have created Prescription Drug Monitoring Programs (PDMP) to try to reduce inappropriate prescribing, dispensing, and related harm. Research assessing whether these interventions are effective has produced inconclusive and contradictory results. Here we examine whether different data sources may have contributed to the varying results. Specifically, we: 1) identify the decisions inherent in creating such a dataset; 2) discuss the public data sources used by researchers in previous work; 3) develop and apply a detailed research protocol to create a novel PDMP law dataset; and 4) to illustrate potential consequences of data choice, apply various data sources to analyze the relationship between PDMP laws and prescribing and dispensing of opioids among disabled Medicare beneficiaries. We find that our dates differ from those in existing datasets, sometimes by many years. The regression analyses generated a twofold difference in point estimates, as well as different signed estimates, depending on the data used. We conclude that the lack of transparency about data assembly in existing datasets, differences among dates by source, and the regression results raise concerns for PDMP researchers and policymakers.

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I. INTRODUCTION

Despite widespread attention in the media, by policy makers, and by states, the burden of opioid-related harm in the United States continues to increase. Drug overdose, which cut short the lives of more than 63,000 Americans in 2016, is now the leading cause of death for Americans under age 50 and is the leading overall cause of accidental death, surpassing deaths from traffic accidents (Centers for Disease Control, 2017). The majority of these deaths, over 42,000, involved opioids (Hedegaard and Minino, 2017). Although the causes of the crisis are varied and complex, it is clear that opioid prescribing, which increased by over 300% from 1999 to 2015, contributed to this seemingly inexorable rise in preventable morbidity and mortality (Guy et al 2017; Kunins 2013, Case and Deaton 2015). States, which have the primary legal role in regulating the prescribing and dispensing of prescription drugs, have taken the lead in attempting to reduce opioid-related harm. They have done so, in part, by creating Prescription Drug Monitoring Programs (PDMPs), databases that collect information on certain medications at the point of dispensing, and in most cases make those data available to authorized users (Davis et al 2014).

Over the past several years, researchers have been doing the critical work of assessing whether these laws and the PDMPs they create have been effective at reducing inappropriate prescribing, dispensing, and opioid-related health harms. To date, the results of these studies have been inconclusive and sometimes contradictory (Davis et al 2017). There are a number of potential reasons for these disparate findings, including that the studies measure somewhat different outcomes and different populations and they often account only for a limited range of policies (mainly PDMP implementation) when states implemented varied packages of laws around the same time. Regardless, recent Federal legislation meant to combat the opioid crisis,

such as the Comprehensive Addiction and Recovery Act of 2016 and the 21st Century Cures Act, all include some funds targeting PDMPs. States will continue to seek best practice around PDMPs as they spend scarce resources on their programs.

Here we consider another explanation for the disparate findings among these studies. In the vast majority of published PDMP studies, the researchers did not independently search for, analyze, and code the relevant laws. Rather, they relied upon third-party information downloaded from the websites of one or more organizations, sometimes coupled with ad-hoc outreach to relevant states. The information gathered typically includes information such as the date each state's PDMP law was enacted and the date the PDMP became operational. However, the dates reported by these public databases often differ, meaning that, at a minimum, results from a study that relies on one data source may not be comparable to those from a study that used another. Moreover, the source of the data published in the public databases themselves is often a black box: None of the websites most commonly used in studies of PDMP effectiveness -- such as those maintained by the National Alliance for Model State Drug Laws (NAMSDL) and The Prescription Drug Abuse Policy System (PDAPS) -- provide publicly available detailed information as to how the dates were determined. The dates used may be underspecified, inconsistent, and potentially inaccurate measures of the relevant state laws, likely to yield conflicting or unreliable results. This paper aims to illustrate the problem, and begin to remedy it by identifying the parameters researchers must address when identifying the dates when states enacted laws authorizing PDMPs as well as when those programs became operational, and publishing a research protocol and sample database of relevant dates assembled by trained legal researchers applying that protocol.

It is foreseeable that researchers will rely on publicly available databases as sources for dates in PDMP studies, particularly when researchers before them have done so. Indeed, using third party sources can be useful in protecting against unconscious researcher bias. However, the websites relied on in the large and growing body of PDMP research typically do not provide information on the definitions of "PDMP program" or other relevant measures, nor do they explain the procedures by which start dates were determined. Therefore, the studies that rely on the data in these public databases also lack such information. In addition, papers that utilize more than one public source of legal information frequently fail to explain how conflicts across data sources were resolved.

The process of constructing a database of laws intended to reduce opioid-related harm such as PDMP laws is complex. In fact, an entire burgeoning field – that of legal epidemiology – is devoted to the appropriate use of law for research purposes (Ramanathan et al. 2017). In the case of PDMPs, identifying the date that a law was "enacted," what would seem to be a straightforward concept, can be difficult. It is even less clear at what point a PDMP became "operational" since these databases often phased in voluntary reporting of data, required reporting of data, and different authorized users gained access to PDMPs at different times. There are also differences in such foundational questions as what constitutes a PDMP at all.

Here we consider how differences in the data sources used in existing PDMP research may have led to varying conclusions regarding important opioid-related outcomes. More specifically, we do four things: 1) identify the decisions a researcher must make to decide which dates to use in a PDMP study; 2) discuss the major public data sources used by researchers studying PDMPs, and, to the limited extent such information is available, summarize the methodology used to construct them; 3) develop a detailed research protocol (Table 1) and apply

it to create a new dataset of dates at which PDMP laws were enacted and became operational (Table 2); and 4) as an illustration of the consequences of data choice, alternatively use the various dates identified in Tables 1 and 2 in an analysis of the relationship between PDMP laws and opioid prescription and dispensing patterns of opioids among disabled Medicare beneficiaries using the sample from our previous work in Meara, et al., 2016 extended by two years to 2014. Throughout we use the term law to include statutes, regulations, and associated legal material.

We draw several conclusions from our research. First, even experienced legal researchers have difficulty creating consistent and reliable measures of PDMP law enactment and operation dates. The complexity of the endeavor can be easily observed in our lengthy research protocol (Table 1). Second, our dates differ a great deal from many of the publicly available dates, sometimes by many years. Third, our tests of the data through regression analyses generated a twofold difference in point estimates, as well as different signed estimates, depending on the data set used. However, as with many other studies, our analyses are identified by the small number of states that adopted laws during the study period. Not surprisingly, therefore, despite large differences in the dates and in the point estimates across identical regressions, the standard errors on our estimates are quite large. We were also unable to reject the null hypotheses that the results were the same across the data in our limited test.

Nonetheless, the lack of transparency about the methods by which data are assembled, the differences among dates depending on the source of the data, and the large differences in the point estimates raise serious for researchers and policymakers. At a minimum, more transparency in the source of data and the protocol by which they were assembled is required.

II. DEVELOPING A LEGAL DATABASE: KEY DECISIONS

a. What is a PDMP?

Assembling even the most basic PDMP legal database requires making important decisions. First, the researcher needs to answer a misleadingly simple question – What is a PDMP? Do the "multiple copy prescription programs" that existed in approximately nine states prior to 1992 (OIG 1992) where, typically, prescribers kept one copy of a prescription, pharmacists kept another and sent a third to a state agency, qualify as a PDMP? Although these programs did not have the capabilities of a modern, electronic system, one might believe that the existence of an early triplicate program represented state attention to pharmaceutical misuse (and therefore, shape the behavior of prescribers, dispensers, and patients), a problem in the state with opioid use, or both. Indeed, some states with early programs had much slower growth in the use of opioids compared with states creating programs after 2000. In fact, there is evidence that at least some of them did affect prescribing decisions, leading to reductions in the prescription of some controlled substances. (Sigler, et al., 1984; Weintraub, Singh, Byrne, Maharaj & Guttmacher, 1991; Hartzema, et al., 1992; Simoni-Wastila, et al., 2004.)

On the other hand, it may not make sense to treat such a program – like the one started in the 1970s in New York or in the 1930s in California – the same way as modern prescription tracking systems, as publicly available datasets often do. Perhaps the most potentially important of these differences is that, although some of these states generated periodic reports based on multiple copy prescription program data, none provided data to clinicians upon request. Where data was accessible to outside entities, those entities were limited to authorized law enforcement and regulatory agencies (OIG, 1992 at 10).

If the researcher decides to define a PDMP as a modern electronic system, she must identify which criteria qualify a system as "modern" and "electronic." Many early electronic

PDMPs required data to be sent only infrequently, such as monthly, and using methods that are now outdated (e.g., mailed via media such as "computer diskette, or magnetic tape." Massachusetts 2004) Are such programs similar enough to a modern PDMP that they should be counted? Or should the relevant factor be not the way data are submitted, but rather how they are accessed? If one of the main goals of a PDMP is to improve clinician decision-making, perhaps they should be counted only if and when they provide web-based access to prescribers or dispensers? Again, there is not necessarily one right answer to these questions, but it is important that they be considered.

b. Enactment date

Another related and perhaps equally important decision involves how to define the enactment date to use. Using the earliest date at which any state law authorized a PDMP (however defined) may be a reasonable choice if the researcher thinks that a benefit of the database is in its signaling potential. But someone trained in legal research can find multiple dates at which government acted or law became effective, most of which are available using proprietary legal databases. For example, one can find the dates at which: (1) a bill authorizing a PDMP was voted on by the state legislature; (2) where necessary, the governor signed the bill into law; (3) a statute became effective by operation of law; and (4) the PDMP may or must be implemented. In some states that last date passes with no evidence that a PDMP has been established.

In choosing the dates to list in the enactment database for this paper, three of us (all lawyers with decades of legal research experience and many years of experience researching controlled substance-related laws specifically) spent many hours considering which of these dates to use. This is not a trivial decision, as these dates can sometimes differ by years and even

shorter discrepancies frequently lead to a difference in the quarter that a law will be counted as "enacted" in a research project based on quarterly outcome data.

There are other reasonable choices to be made. However, it is critical that the choices are transparent. For example, consider Arkansas' act, which the legislature voted on in March 2011, became effective in July 2011, but which states that the PDMP "shall become operational March 1, 2013, *if full funding is available* (emphasis added)." We use March 2013 as the enactment date, with a notation regarding 2011, because it is clear from the statute that the program would not be in effect, at the earliest, until 2013. This state also highlights another potential source of divergent dates. Both NAMSDL and PDAPS use March 2011 as the enactment date, while we use July 2011 for the secondary date because even though the law was approved in March 2011, laws in Arkansas do not generally become effective until 90 days after the legislature adjourns. In this case, the official effective date of the law, which we use, is July 27, 2011. We are not claiming that our approach is necessarily better, but rather noting that these decisions – decisions which are often entirely opaque - are important. When one is identifying the effectiveness of laws by the quarter, even the difference between March and July in the same year matters.

c. Operational Date

In nearly all states the enactment dates do not correspond to the date the PDMP began operations because the operation of the PDMP is dependent on funding being separately authorized, regulations being issued, or other reasons. Therefore, the researcher may wish, instead, to use the date the PDMP became "operational." Contrary to our expectations beginning this research, we found it easier to apply consistent rules in assembling the database of operational dates. Nonetheless, it was still difficult to define "operational." Does "operational" mean the date that the PDMP began gathering information? The date it began requiring

physicians or pharmacists to report data? The date it began gathering information via a particular mechanism (such as via the internet)? The date it began making data readily available to certain users, such as law enforcement agencies or clinicians? As with the definition of what makes a PDMP and when the relevant legislation is enacted, there is not necessarily one right answer to this question, but the choice made matters.

Sometimes answers to these questions are in statutes, sometimes in related regulations, and sometimes in the "frequently asked questions" sections of online PDMP guides or other sources. Even if a skilled researcher has the expertise to interpret laws and access to all of the sources necessary to do so, to complete even the simplest databases often requires contacting state officials and finding the people who remember the history of their PDMP implementation. Following the protocol discussed in Table 1, that is what we have done in assembling our database of PDMP operational dates, which we define as the date the end user became able to access PDMP data.

III. PDMP ESTABLISHMENT/ENACTMENT AND OPERATIONAL DATES

a. Public Sources

Three publicly available sources have been used in PDMP studies. Here we discuss each of them in turn. In addition, we have provided a Table with dates that each database reports for PDMP statute enactment and operational dates, including the date at which a data collection began. See Table 3.

i. The National Alliance for Model State Drug Laws (NAMSDL)

NAMSDL is a nonprofit organization partially funded by the United States Department of Justice that provides information to states on drug policies and law. NAMSDL is mentioned as a data source in many papers regarding PDMPs. See, e.g., Bao et al. (2016), Deyo et al. 2013,

Morgan, et al. (2012), Nam et al. (2017), Pardo (2017), Paulozzi, Kilbourne & Desai (2011), Patrick et al. (2016), Simoni-Wastila & Qian (2012), and Dowell et al (2016).

NAMSDL maintains a webpage, last updated in 2014, that includes a downloadable report which lists PDMP "Date of Enactment," "Date Collection Began," and the "Date of User Access" (NAMSDL, 2014). None of these terms are defined. According to the website, "research is conducted using nationwide legal database software, individual state legislative websites and direct communications with state PDMP representatives." (NAMSDL, 2014) Although dates are missing for some states in each list of dates, the Date of Enactment is most complete (missing only Nebraska and Pennsylvania). Therefore, we use those dates in the analyses below.

ii. The Prescription Drug Abuse Policy System (PDAPS)

PDAPS is a project developed by a for-profit organization, Legal Science, LLC, in collaboration with Temple University's center for Health Law, Policy, and Practice. The project is a built on The Policy Surveillance Program, a policy surveillance and legal mapping tool funded by the Robert Wood Johnson Foundation. PDAPS is funded by the National Institute on Drug Abuse to track key state laws related to prescription drug abuse. (One of us, Corey Davis, serves, without compensation, on the expert advisory committee). PDAPS is mentioned as a data source in many papers regarding PDMPs including Buchmueller and Carey (2018), Nam et al. (2017), Pardo (2017), and Simoni-Wastila & Qian (2012).

PDAPS operates a website with extensive data listings. One web page entitled "PDMP Implementation Dates," includes listings of dates (month, day, year) related to various aspects of PDMPs (http://www.pdaps.org/datasets/pdmp-implementation-dates). According to the website, these dates "were compiled through contact with PDMP administrators from each state program

by Brandeis' PDMP Training and Technical Assistance Center (TTAC)." In our analyses we use data answering question 1.1, "When was the PDMP enabling legislation first enacted?" question 1.2, "When did the PDMP become operational?" and 1.3 "When did the PDMP first allow authorized users to access the data?"

In most but not all cases the dates on this webpage coincide with the dates listed on the Brandeis TTAC website. We therefore also used a separate source of data from the PDAPS website. In addition to the data from Brandeis, PDAPS conducted its own, independent review of PDMP laws. We utilized two questions from this dataset, both of which roughly correspond to our questions of interest: Question 1, "Does this state have laws authorizing access by a professional to a PDMP system?" and Question 2: "Does this state have a law requiring dispensers to report data to the PDMP?"

iii. The Prescription Drug Monitoring Program Training and Technical Assistance Center (TTAC)

The Brandeis University TTAC "provides a comprehensive array of services, support, resources, and strategies to PDMPs, federal partners and other stakeholders to further the efforts and effectiveness of PDMPs in combating the misuse, abuse and diversion of prescription drugs" (PDMP Assist, last checked June 7, 2018). The TTAC is mentioned as a data source in many papers regarding PDMPs including Buchmueller and Carey (2018), Nam et al (2017), Powell et al, (2016), and Patrick (2016).

The TTAC "web site is funded through a grant from the Bureau of Justice Assistance, Office of Justice Programs, U.S. Department of Justice." The website includes a table that lists the "Year PMP Legislation enacted" and "Year PMP Became Operational." We were unable to find anything on the site regarding the source of the primary information or the research methods

used to collect it. Although many scholars cite the TTAC as the source of their data, no months are reported that would allow a scholar to analyze data at a more precise time period than the annual level (ttp://www.pdmpassist.org/content/pdmp-legislation-operational-dates). In addition, PDAPS states that it relies on TTAC data. Therefore, although a few of the dates in the PDAPS and TTAC sites differ, we rely on PDAPS to represent the TTAC data and do not examine them separately.

b. Original Databases

We constructed an original database of dates representing the month and year of PDMP Enactment and Operation (See Table 2). We initially set out to define two sets of dates to correspond with the dates available in the NAMSDL and PDAPS data, one based on enactment of the legislation and another based on first operation of the PDMP. Because we could not apply these broad definitions consistently across states, we report four sets of dates described below and in Tables 1 and 2.

First, a lawyer-librarian or a law student researcher supervised by a lawyer-librarian established a date for each state applying the research protocol in Table 1. Second, the four authors who are legal researchers on this project discussed each date and the supporting evidence. In many cases, we required additional research, including phone calls to state authorities, to establish a final date. This process took place during frequent meetings from January through May 2018. A detailed report documenting all sources supporting our original database is on file with the authors.

In summary, we define the main enactment date – Enactment/Legislated Start Date Any PDMP -- as the month and year in which a PDMP statute stated that dispensers or prescribers would be first required to either a) send, via mail or fax, physical copies of written or filled

prescriptions to a central database or b) send, via electronic methods, data regarding written or dispensed prescriptions to a central database, whichever was earlier. (Table 1, Table 2 Column 1). This definition includes the older "triplicate" form systems. Because outcome data typically only spans a decade or two at the most, unless it was straightforward to identify a start date that occurred before January 1, 1990, we report the date as pre-1990.

As explained in Table 1, for the paper-based programs we used the month and year that the state first required that physical copies of prescriptions be sent to the relevant agency or board in Table 2, Column 1. For programs that began as electronic systems we used the month and year at which the relevant law that authorized the database stated that the PDMP must begin operation. Therefore, if a statute was passed by the legislature and signed by a governor in June 2004 but the language of the statute required that the program begin by January 2005, we use the latter date.

We made the decision to use this later date, where relevant, rather than the date of statutory enactment because we were mainly interested in when a provider would reasonably understand the law to have practical effect. Indeed, in some cases, the statutes used authorizing or aspirational language, stating that a state may or should if possible create a PDMP, language that a provider would be unlikely to understand as binding. Second, the definition of enactment date of statutes is difficult to identify because it differs by state. In some states, it is reasonable to count the date at which a statute is passed by the legislature. In other states, one would use the date the governor signed the bill. In still others, there are rules that a signed bill does not become a law for a specified number of months. These and other differences make identifying a consistent enactment date across states quite difficult. Others may make a different judgment,

perhaps believing that press coverage of a legislature passing a bill regardless of content would have a signaling effect that could change provider behavior.

We include a second measure of enacted/legislated start dates for the eleven states with statutes that indicated that the program start was contingent on receiving funding (Table 1, Column 2). For those states, Column 1 includes the date at which that funding became available. We made this choice because, for these states, the authorizing statute is more aspirational than operative. No action could happen unless and until funds became available. Because neither approach – using the date the act was passed or the approach we use -- is entirely satisfactory, we include an additional column called Enactment/Legislated Start Date, Contingent on Funding. Table 2, Column 2 lists the earlier date at which the statute was passed. Nonetheless, four of the relevant states (GA, IA, ME, MD) received funding at the same time the statute indicated the program would be effective if funding were received.

We include a third measure of Enactment/Legislated Start Date to allow researchers to have a complete set of statutory dates for only modern electronic programs. Because the older paper programs and modern electronic programs differ a great deal, we provide an additional column – Enactment/Legislated Start Date: Electronic -- for those states that had paper programs and later transitioned to electronic programs. The date on which those transitions occurred are displayed in Table 2, Column 3.

Finally, we include a measure of the operational date of a PDMP which reflects the month and year at which PDMP data became accessible to any party authorized to access it (e.g., physician or pharmacist) (Table 2, Column 4). Different programs allowed or required access to physicians, pharmacists, members of law enforcement, or others. Therefore, the database may

represent the date at which, for example, physicians in some states or pharmacists in another were granted access.

Some states operated pilot programs, allowing access to a small number of end users; we report the date at which the full program became operational and not the earlier date at which the pilot program began. We count a program as operational if the end user can access a database directly through a computer, rather than through a phone call or fax.

IV. METHODS FOR EMPIRICAL ANALYSES

A. Data and Empirical Approach

In addition to producing novel, transparent, and reproducible enactment and operational dates, we test whether using different dates yields different results when measuring the effectiveness of PDMPs on opioid-related outcomes. More specifically, we examine the relationship between these different representations of whether and when a PDMP law was enacted or a PDMP implemented and opioid outcomes among disabled Medicare beneficiaries.

Using the same sample as in Meara et al., 2016 covering 2006-2012 with the addition of data for 2013 and 2014, we examine Medicare beneficiaries from a 40 percent random sample of Medicare beneficiaries 21 to 64 years of age, eligible for Medicare on the basis of disability, alive, and continually enrolled in Medicare fee-for-service parts A, B, and D in a calendar year. We excluded patients with cancer diagnoses, with end-stage renal disease, or who were receiving hospice care to remove those likely to receive opioids for palliative care.

Some of the publicly available datasets were missing data for some states. In our main specifications we deleted those states from our analyses to make the results comparable and so we could perform additional statistical tests across the models, leaving us with 34 states. In total we observe over 6.1 million patient years. However, in sensitivity testing we performed the

same analyses applying our original data (Table 1) to all forty-nine states with a PDMP (excluding Missouri, which did not enact a PDMP law until 2017).

We estimate the following Ordinary Least Squares regressions:

$$\text{Opioid Measure}_{it} = \beta_o + \beta_1 \text{PDMP}_{it} + \beta_2 \text{Year}_t + \beta_3 \text{State}_{it} + \beta_4 X_{it} \quad (1)$$

where the "Opioid Measure" for individual i in year t is alternatively one of two outcomes. First we test the milligrams of morphine equivalents (MME) annually dispensed to a beneficiary. Then, following Buchmueller et al. (2018), we estimate whether a patient filled any opioid analgesic prescription in five or more pharmacies in a year. Models include a fixed effect, State_{it}, for the state of residence an individual, i, lives in at time t, and a fixed effect, Year_t, for each year, and a vector X_{it} of patient characteristics. Patient characteristics include: sex, African-American, other race (white is reference race group), Hispanic ethnicity, indicators for age (21-29, 30-39, 40-49, 50-59, and 60 – 64), receipt of any Medicare Part D low income subsidy (as a proxy for poverty), whether beneficiary was dually eligible for Medicaid, any diagnosis of depression, a diagnosis of bipolar disorder, and a diagnosis of musculoskeletal disorder. We include all opioids listed in Meara et al. (2016) as well as tramadol, which has been a schedule IV controlled substance since 2014 and has typically been included in other papers describing opioid prescribing.

In these models, the coefficient of interest is $\beta_{1,}$ which describes the effect of having a PDMP in a given state in a given year on our outcomes. To estimate $\beta_{1,}$ we use the various measures of the date at which a state enacted a PDMP law or began operating a PDMP (see Tables 1 and 2). The PDMP variable took on values of 0 in years before it was, depending on the database used, enacted, operational, or accessible to users, values of 1 for each full year it

was in place, and the share of months the PDMP was enacted, operational, or accessible for any partial year. A PDMP enacted any time in July of 2007, for example, would have a value of .5 for 2007 and 1 thereafter. Where a database did not list a month, we coded the law as in place for 0.5 years for the first year of enactment, operation, or access.

V. RESULTS

a. Database Results

As can be seen by comparing Table 1 (reporting the start dates we assembled applying the protocol in Table 1) and Table 3 (reporting the start dates from publicly available databases), there are large differences between our dates and publicly available dates. In many cases, expertise interpreting statutes is required. For example, a few statutes, such as those in Arizona and Nebraska, were enacted in jurisdictions in which the official enactment date is a specified number of months after the legislature passes a bill or a governor signs it. In addition, decisions of whether to round to a previous or next month or year when a day is provided as part of a date can have large effects on estimates, particularly when research is organized at the quarterly level and a limited number of years are used in samples. In some cases, the publicly available data do not provide a month or any date at all. Sometimes, as is the case of some of NAMSDL's measures for Idaho, only a season is listed. In our empirical tests, because the dates came before the study period, this had no effect, but it may well matter for other analyses.

Although it can be hard to trace details, it is often important to do so. For example, many statutes declare that a PDMP will be implemented contingent on funding. Sometimes funding was contemporaneous with the statute enactment. But, as can be seen in Table 1, Column 3, in many states that funding came later. In Washington, for example, the funding arrived four years later. It may be more appropriate, therefore, to use the date funding was appropriated in this and

similar cases. Moreover, a researcher who lists a date from a third-party source, without reading the statute, would miss the fact that the statute itself does not give a start date at all; in fact, news coverage shows the program was abandoned fully in 2008 due to budgetary issues and did not launch until 2012, an important fact that would be missed. (Ho, 2008; Harshman, 2011; Farley, 2011)

In addition, dates among publicly available databases also differ a great deal. For example, consider that PDAPs uses the earliest paper systems as enactment and operational dates, sometimes for very large states such as California, which it codes as 1938. NAMSDL, conversely, lists California as enacting a PDMP in 2003. This divergence can have an important effect, particularly as studies that rely on the PDAPS date might simply exclude California from their analyses by coding it as having started before the study period.

b. Quantitative Results

As in Meara et al. (2016), in which we tested the relationship between various opioid regulations and outcomes among the Medicare disabled population, we find no statistically significant relationship between the enactment of a PDMP statute, operation of a PDMP program, or first date of user access to an electronic PDMP and the annual MME dispensed to disabled Medicare beneficiary between 2006 and 2014. (Table 4). However, what is of interest for this analysis is the very large differences in the point estimates when data from the different databases are used.

The mean annual MME dispensed in a year in our population ranges from 5,290 in 2006 to a peak of 6,839 in 2010. In regression results, three of the four of the associations between enactment of a PDMP and average annual MME dispensed per beneficiary are positive. Using our own dates for enactment/legislated start date (Table 2, Column 1), the coefficient on the

PDMP is only about one third (93.23 mgs morphine equivalent per year per beneficiary, Table 4, Column 1) of the same coefficient using dates provided by the publicly available data. Using PDAPs dates for enabling legislation (Table 3, Column 1), we find an increase of 274.6 MME per year (Table 4, Column 3). Using NAMSDL's dates for enactment of legislation (Table 3, Column 4), we find an increase of 269.0 MME per year (Table 3, Column 4).

These results are highly dependent on the type of system to be enacted, paper or electronic. Using an alternative measure of enactment/legislated start date, one that restricts enactment dates to modern electronic system (Table 2, combining Columns 1 and 3), we find a decline in annual morphine equivalents dispensed of 71.52 MME associated with the variable (Table 4, Column 2).

Large differences in the estimates can also be seen when applying different sources representing operational dates. Using our dates representing when a PDMP became operational in terms of the end user being granted access to the database (Table 2, Column 4), we find an effect of negative 69.77 MME annually (Table 4, Column 7) whereas the other databases identify much smaller magnitudes. For example, PDAPS' dates for when a PDMP became operational (Table 3, Column 2) show an associated 13.24 mg decline (Table 4, Column 5) and for user access (Table 3, Column 3) show an associated 40.96 mg decline (Table 4, Column 8). Similar measures using NAMSDL's dates (Table 3, Columns 5 and 6) show a 26.99 and 43.85 mg decline respectively (Table 4, Columns 6 and 9).

We also test the relationship between different PDMP start dates and the probability that a beneficiary received opioids from five or more unique pharmacies in a year. Unlike the estimates for mean MME dispensed, many of these results are statistically significant.

Nonetheless, of primary interest to this analysis is the very large differences, both in magnitude and sign, of the point estimates.

The mean probability that a beneficiary obtained opioids at five or more pharmacies in a year from 2006-2014 is 1.7 percent. In regression results, most associations between enactment of a PDMP and this measure of a high number of pharmacies are positive and statistically significant. Using our own dates for enactment/legislated start date (Table 2, Column 1), the coefficient on enactment of a PDMP is just over a quarter of the same coefficients using similar measures of enactment dates provided by the publicly available data. We find a 0.06 percentage point increase in the probability a beneficiary received prescriptions from five or more pharmacies (Table 5, Column 1), whereas using PDAPS' dates for enabling legislation (Table 3, Column 1), we find an increase of 0.211 percentage points (Table 5 column 3) and using NAMSDL's dates for enactment of legislation (Table 3, Column 4) we find an increase of 0.209 percentage point (Table 5, Column 4). These numbers represent increases of 3.5, 12.4, and 12.3 percent in the probability of dispenses at five or more pharmacies.

However, like the results for annual MME dispensed, the estimated effect of PDMPs on filling opioid prescriptions at multiple pharmacies are highly dependent on the definition of PDMP date applied. Using our second measure of enactment, one that restricts enactment dates to modern electronic system (Table 2, Columns 1 and 3), we find a statistically significant decline of 0.062 percentage points (Table 5, Column 2) in the probability of dispenses at five or more pharmacies, which represents a 3.6 percent decline associated with the intervention.

Large differences in the estimates also can be seen when applying different sources representing operational dates. Using our dates representing when a PDMP became operational in terms of the end user being granted access to the database (Table 2, Column 4), we find a

statistically significant decline of .068 percentage points (Table 5, Column 7) in the probability of dispenses at five or more pharmacies, whereas the other databases identify much smaller declines or increases, none of which are statistically significant. For example, PDAPS' dates for when a PDMP became operational (Table 3, Column 2) show an associated 0.012 percentage point increase (Table 5, Column 5) and for user access (Table 3, Column 3) show an associated 0.029 percentage point decrease (Table 5, Column 8) in five or more pharmacies. Similar measures using NAMSDL's dates (Table 3, Columns 5 and 6) show a 0.0004 percentage point increase and a .03 percentage point decrease respectively (Table 5, Columns 6 and 9).

VI. DISCUSSION AND CONCLUSION

Across multiple analyses, different sources of data and different definitions of start dates yield very different results – sometimes by an order of magnitude. We suspect that some of the differences among varying conclusions regarding whether PDMPs are effective can be explained by the fact that different researchers have used different data sources. The large differences in the point estimates seen in Tables 4 and 5 lend support to this view. Our results were based on a sample including a limited number of years and, therefore, effects were identified upon a limited number of states. Other studies will not be based on this same sample, and the results could well be quite different. We repeated the models above on a sample of 49 states, excluding Missouri which did not yet have a PDMP by the end of 2015.

The specific estimates reported here are merely illustrative. We hope to draw more general lessons. First, when state policy interventions such as the implementations of PDMPs contain many facets or combinations of individual strategies, all of which evolve over time, it can be difficult for researchers to create measures of the interventions even within a single state. Creating such measures for fifty states over time raises an enormous challenge. Blank (2002)

discussed similar difficulties in disentangling state approaches to welfare reform in the 1990s, and the way these problems played out in evaluating welfare reform.

Second, and likely our most important conclusion, is that in attempting to evaluate the effects of legal policy, researchers must understand both how interventions work on the ground and how they are represented in legal sources. They must have the expertise to read and interpret laws accurately. To that end, we have presented a model of a research protocol that accounts for some differences in types of PDMPs and applied it to generate a database of various enactment and operational dates.

Other researchers may reasonably make different choices than we did when deciding how to code a state law or whether and how to use third party sources. That is to be expected. In all cases, the desire to draw upon a seemingly objective source of legal dates must be weighed against the appropriateness of a data source for the research question at hand. Nonetheless, it is important to allow those who use research, including policymakers who base decisions on research, to evaluate those choices. It is challenging to do so when researchers rely on sources that do not make their research protocols available or do not report their own research methods.

Although there is no one correct approach to measuring PDMP laws, regardless of the study design, protocols need to be implemented consistently and transparently. Researchers should acknowledge the limitations of any given decision. Overstating the benefits of an ineffective program wastes scarce resources, while understating its benefits will slow action to expand a successful effort. Given the stakes for so many lives, it is critical that this body of research is based on transparent methods.

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Table 1: Research Protocol and Data Descriptions

As described in the text, we set out to define two sets of dates to correspond with the publicly available dates – one based on enactment of the legislation and another based on when the PDMP became operational. Because we could not apply these broad definitions consistently across states, we report four sets of dates. The first three are related to the enactment/legislated start date of the statute authorizing or requiring a PDMP. The fourth date reports when a modern, electronic system became operational in terms of allowing an intended user to access the system.

I. **Enactment/Legislated Start Dates – Table 2, Columns 1 through 3.**

A. *Table 2, Column 1, Enactment Date/Legislated Start Date -- Any PDMP*. This column contains the month and year that the legislation states dispensers or prescribers would be first required to either a) send, via mail or fax, physical copies of written or filled prescriptions to a central database or b) send, via electronic methods, data regarding written or dispensed prescriptions to a central database.

A small number of states required copies of paper prescriptions to be sent to a central repository. For these states, we note the month and year that these statutes required copies of paper prescriptions to be sent in Table 2, Column 1. (NB: some states had required prescribers or dispensers to keep records of prescriptions but not send them to a central repository – we do not code those states as having a PDMP).

For all other states, this column contains the month and year that a statute or regulation that authorized an electronic database to which information on dispensed prescriptions is required to be reported went into effect, subject to the following caveats:

1. If the statute is clear that the PDMP would not be required to exist until a date after the effective date of the statute, we note the date by which the PDMP is required to exist, not the effective date of the statute.
2. If the statute authorizes the PDMP contingent upon receipt of sufficient funding, we include the date that we find evidence that such funding was obtained by reaching outside the statute using the same protocol we used for determining the operational date as described below.

B. *Table 2, Column 2, Enactment/Legislated Start Date – Contingent on Funding.* For the eleven states in which the statute makes PDMP operation contingent on funding, we include the date at which the statute authorizing the development of a PDMP contingent on funding was enacted. This date is typically, although not always, earlier than the date the funding is received. We report this date because researchers may believe that the existence of a statute, even one that it inoperative, may influence provider behavior and because it may be useful in analyzing that question or in sensitivity analyses.

C. *Table 2, Column 3, Enactment/Legislated Start Date Electronic.* For the twelve states, including some very large states, that had a paper-based system before they implemented an electronic system, we include an additional column listing the month and year that the state enacted (according to the definition above), a modern, electronic PDMP.

II. **Modern System Operational Date**: These dates are meant to represent the month and year that PDMP data became accessible to any user (e.g., physician, pharmacist, or member of law enforcement) authorized by state law to receive it. Many programs began requiring reporting before they began permitting or requiring prescribers, pharmacists, or others to query the database. In these cases, we report the latter date, the date at which the database became operational from the perspective of the end user. In addition, some states operated pilot programs, allowing access to a small number of end users; we report the date at which the full program became operational and not the earlier date at which the pilot program began. We count a program as operational if the end user can access a database directly, rather than through a phone call or fax because the latter are unlikely to allow the physician to access patient histories. We determined this date from the following sources:

a. State Statutes. Some statutes state a date by which the PDMP must be accessible to users. We used these dates as a starting point for our research, and confirmed these dates with or updated them from the additional sources listed in b-d below.
b. Regulations.
c. Subregulatory materials such as policy documents or manuals from the agency that operates the PDMP.
d. Other sources, including but not limited to:
    i. State government reports on the PDMPs (e.g., those listing start dates and/or statistics on operations).
    ii. Presentations by regulators (e.g., powerpoint presentations with summary stats)
    iii. Medical or Pharmacy Board Announcements
    iv. FAQs and historical materials sections of the state PDMP website
    v. Phone calls to relevant governing agency
    vi. In rare cases, we rely on press reports. If there are conflicting press reports, we make phone calls to the governing agency.

Table 2: PDMP Enactment/Legislated Start and Operational Dates

	(1)	(2)	(3)	(4)
Jurisdiction	**Enactment/ Legislated Start Date**	**Enactment/ Legislated Start Date: Contingent on Funding**	**Enactment/ Legislated Start Date: Electronic**	**Modern System Operational/User Access**
Alabama	Nov-05	Aug-04		Apr-06
Alaska	Sep-08			Jan-12
Arizona	Sep-07			Dec-08
Arkansas	Mar-13	Jul-11		May-13
California	Pre-1990		Jan-05	Sep-09
Colorado	Jun-05			Feb-08
Connecticut	Oct-06			Jul-08
Delaware	Sep-11	Jul-10		Aug-12
DC	Feb-14			Oct-16
Florida	Dec-10			Oct-11
Georgia	Jul-11	Jul-11		May-13
Hawaii	Pre-1990		Dec-96	Feb-12
Idaho	Pre-1990		Apr-00	Apr-08
Illinois	Pre-1990		Apr-00	Dec-09
Indiana	Pre-1990		Jul-07	Jul-07
Iowa	May-06	May-06		Mar-09
Kansas	Jul-08			Apr-11
Kentucky	Jul-98			Jul-99
Louisiana	Jul-06			Jan-09
Maine	Jan-04	Jan-04		Jan-05
Maryland	Oct-11	Oct-11		Dec-13
Massachusetts	Dec-92		Feb-13	Jan-11
Michigan	Pre-1990		Jan-02	Jan-03
Minnesota	Jan-09	Jul-07		Apr-10
Mississippi	Jun-06			Jul-08
Missouri	Jul-17			
Montana	Jul-11			Oct-12
Nebraska	Aug-11			Jan-17
Nevada	Jan-96			Feb-11
New Hampshire	Jun-12			Oct-14
New Jersey	Aug-09			Jan-12
New Mexico	Jul-04			Aug-05
New York	Pre-1990		Oct-06	Jun-13
North Carolina	Jan-06			Jul-07
North Dakota	Dec-06	Apr-05		Oct-08
Ohio	May-05			Oct-06

Oklahoma	Jan-91			Jul-06
Oregon	Jul-09			Sep-11
Pennsylvania	Pre-1990		Jun-15	Aug-16
Rhode Island	Pre-1990		Aug-95	Sep-12
South Carolina	Jun-06			Feb-08
South Dakota	Mar-10			Mar-12
Tennessee	Jan-03			Jan-10
Texas	Aug-81		Sep-99	Aug-12
Utah	Jul-95			Jan-06
Vermont	Jun-08	May-06		Jan-09
Virginia	Sep-03			Jun-06
Washington	Aug-11	Jul-07		Jan-12
West Virginia	Jun-95		Sep-02	May-13
Wisconsin	Jun-10			Jun-13
Wyoming	Jul-03			Jul-13

Source: Data created by authors using protocol listed in Table 1 during the winter and spring 2018. A detailed report of all sources consulted is on file with the authors.

Notes: All dates established according to research protocol detailed in Table 1. The Enactment Date Any PDMP column lists the month and year each state required a dispenser or prescriber to report a written or filled prescription, including paper submissions. For statutes that explicitly required a state to secure funding before requiring reporting, we included the date at which the funding was secured as well as the earlier date at which the statute was passed in a second column, the Contingent on Funding Enactment column. The Enactment Date Electronic column lists the month and year that the state enacted a modern, electronic PDMP. The Modern System Operational Date represents the month and year that PDMP data became accessible to any user (e.g., physician, pharmacist, or member of law enforcement) authorized by state law to receive it.

Table 3: Enactment and Operational Dates Publicly Available Sources

	(1)	(2)	(3)	(4)	(5)	(6)
Jurisdiction	PDAPS Enabling Legislation	PDAPS Operational	PDAPS User Access	NAMSDL Enactment	NAMSDL Collection Began	NAMSDL User Access
Alabama	May-05	Dec-05	Jun-07	May-04	Apr-06	Aug-07
Alaska	Sep-08	Jul-11	Dec-11	Jun-08	Aug-11	Jan-12
Arizona	Sep-07	Sep-08	Nov-08	Jul-07	Oct-08	Dec-08
Arkansas	Mar-11	Feb-13	May-13	Mar-11	Mar-13	Mar-13
California	Dec-38	Dec-38		Sep-03	1998	2009
Colorado	Jun-05	Jun-07	Feb-08	Jun-05	Jul-07	Feb-08
Connecticut	Jun-06	Jun-08		Jun-06	Jul-08	
Delaware	Jul-10	Feb-12	Aug-12	Jul-10	Mar-12	Aug-12
District of Columbia	Feb-14			Feb-14		
Florida	Jun-09	Aug-11	Oct-11	Jun-09	Sep-11	Oct-11
Georgia	May-11	Jun-13	Jun-13	May-11	Jul-13	Jul-13
Hawaii	Dec-42	Dec-42		Jun-96		
Idaho	Dec-66	Dec-66	May-99	Apr-00	fall 1997	spring 1998
Illinois	Dec-60	Dec-67		Aug-99		
Indiana	Dec-96	Dec-97		Mar-06	1994	2007
Iowa	May-06	Dec-08	Mar-09	May-06	Jan-09	Mar-09
Kansas	Jun-08	Jan-11	Mar-11	Apr-08	Feb-11	Apr-11
Kentucky	Jul-98	Dec-98	Jun-99	Apr-98	Jan-99	Jul-99
Louisiana	Jun-06	Oct-08	Dec-08	Jun-06	Jun-08	Jan-09
Maine	Jun-03	Jun-04	Dec-04	Jun-03	Jul-04	Jan-05
Maryland	May-11	Aug-13	Dec-13	May-11	Aug-13	Jan-14
Massachusetts	Dec-91	Dec-93		Aug-10		
Michigan	Dec-87	Dec-88		Jan-02	Jan-03	Feb-03
Minnesota	Jun-07	Jan-10	Apr-10	May-07	Jan-10	Apr-10
Mississippi	Dec-04	Dec-04	Nov-05	Apr-06	2005	Dec-05
Missouri				No program		
Montana	Jun-11	Mar-12	Oct-12	Apr-11	Mar-12	Oct-12
Nebraska	Apr-11	Apr-11	Apr-11			
Nevada	Jun-95	Dec-96	Jun-97	Jul-95	Jan-97	Apr-97
New Hampshire	Jun-12	Sep-14	Oct-14	Jun-12	Oct-14	Oct-14
New Jersey	Jan-08	Aug-11	Jan-12	Jan-08	Sep-11	Jan-12
New Mexico	Jul-04	Dec-04	Jul-05	Jul-04	Jan-05	Aug-05
New York	Dec-71	Mar-73	Jan-10	Apr-73		
North Carolina	Aug-05	Jun-07	Sep-07	Aug-05	Jul-07	Oct-07
North Dakota	Nov-05	Aug-07	Aug-07	Apr-07	Jan-07	
Ohio	May-05	Jun-06	Oct-06	Dec-04	Jan-06	Oct-06
Oklahoma	May-90	Dec-90		May-90	1990	Jul-06
Oregon	Jul-09	May-11	Aug-11	Jul-09	Jun-11	Sep-11
Pennsylvania	Dec-71	Dec-72				

Rhode Island	Dec-77	Dec-78		Nov-01		
South Carolina	Jun-06	Jan-08	Aug-08	Jun-06	Feb-08	Jun-08
South Dakota	Mar-10	Dec-11	Feb-12	Mar-10	Dec-11	Mar-12
Tennessee	Dec-02	Nov-06	Dec-06	May-90		
Texas	Aug-81	Dec-81	Dec-81	Jun-89		
Utah	Dec-94	Dec-95	Dec-96	Jan-95	Jan-97	Jan-97
Vermont	May-06	Dec-08	Mar-09	May-06	Jan-09	Apr-09
Virginia	Apr-02	Aug-03	May-06	Apr-02	Jun-06	Jun-06
Washington	Jul-07	Oct-11	Jan-12	May-07	Oct-11	Jan-12
West Virginia	Jun-95	Jun-95		Mar-95		
Wisconsin	May-10	Mar-13	May-13	May-10	May-13	May-13
Wyoming	Mar-03	Jun-04	Sep-04	Mar-03	2004	2004

Sources: Data downloaded by authors between January and May 2018. Columns 2-4 are from the Prescription Drug Abuse Policy System, http://pdaps.org/datasets/pdmp-implementation-dates (last checked April 26, 2018). Column 2, Enabling Legislation, is from survey question 1.1 question – When was the PDMP enabling legislation first enacted?. Column 3, Operational, is from survey question 1.2 When did the PDMP become operational?, Column 4 User Access, is from survey question 1.3 When did the PDMP first allow authorized users to access the data?. Dates in columns 5-7 are from the National Alliance for Model State Drug Laws, PMDP Dates of Operation Report http://www.namsdl.org/library/580225E9-E469-AFA9-50E7579C1D738E71/ (last checked April 26, 2018).
Notes: Empty cells and cells with no month listed reflect the data as reported in the original sources. For cells in which only a year was reported, we assigned the year a value of 0.5 in the regression analyses. Those cells for which only a season was reported did not matter for the regression analyses since the years were before the study periods.

Table 4. Estimated Associations between Annual Morphine Equivalent Dispensed and PDMP Enactment and Operational Dates from Various Sources, 2006-2014

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Enactment/Enabling/Legislated Start Dates				Operational – Collection or Other		Operational – User Access		
VARIABLES	Horwitz et al (any PDMP)	Horwitz et al., (electronic, where applicable)	PDAPS Enabling Legislation	NAMSDL Enactment	PDAPS Operational	NAMSDL Collection Began	Horwitz et al. Modern System Operational	PDAPS 1.3 User Access	NAMSDL User Access
PDMP effect	93.23	-71.52	274.6	269.0	-13.24	-26.99	-69.77	-40.96	-43.85
	(150.2)	(204.9)	(193.1)	(193.5)	(198.8)	(217.1)	(205.7)	(208.8)	(206.6)
Female	-573.0***	-573.0***	-572.9***	-573.0***	-573.0***	-573.0***	-573.0***	-573.0***	-573.0***
	(81.14)	(81.17)	(81.05)	(81.06)	(81.15)	(81.15)	(81.16)	(81.19)	(81.19)
Black	-3,571***	-3,571***	-3,571***	-3,571***	-3,571***	-3,571***	-3,571***	-3,571***	-3,571***
	(368.7)	(368.8)	(368.5)	(368.5)	(368.8)	(368.8)	(368.8)	(368.7)	(368.7)
Other Race	-2,234***	-2,234***	-2,234***	-2,234***	-2,234***	-2,234***	-2,234***	-2,234***	-2,234***
	(389.0)	(389.2)	(389.0)	(389.0)	(389.2)	(389.1)	(389.2)	(389.2)	(389.2)
Hispanic	-3,458***	-3,458***	-3,458***	-3,458***	-3,458***	-3,458***	-3,458***	-3,458***	-3,458***
	(851.5)	(851.9)	(851.3)	(851.3)	(851.8)	(851.9)	(851.9)	(851.9)	(851.9)
Part D low income subsidy	638.6***	638.9***	639.3***	639.3***	638.7***	638.7***	638.9***	638.8***	638.8***
	(187.8)	(188.0)	(188.2)	(188.2)	(187.9)	(188.0)	(188.0)	(188.0)	(188.0)
Dual eligible for Medicaid	-1,593***	-1,593***	-1,593***	-1,593***	-1,593***	-1,593***	-1,593***	-1,593***	-1,593***
	(166.9)	(166.9)	(167.1)	(167.1)	(166.9)	(166.9)	(167.0)	(167.0)	(167.0)
Depression dx	2,451***	2,450***	2,451***	2,451***	2,450***	2,450***	2,450***	2,450***	2,450***
	(96.10)	(96.19)	(96.12)	(96.12)	(96.15)	(96.16)	(96.20)	(96.17)	(96.17)
Bipolar diagnosis	-2,827***	-2,827***	-2,827***	-2,827***	-2,827***	-2,827***	-2,827***	-2,827***	-2,827***
	(169.2)	(169.3)	(169.2)	(169.2)	(169.3)	(169.3)	(169.3)	(169.3)	(169.3)
Musculoskeletal diagnosis	7,991***	7,991***	7,991***	7,991***	7,991***	7,991***	7,991***	7,991***	7,991***
	(371.1)	(371.1)	(371.2)	(371.2)	(371.1)	(371.1)	(371.1)	(371.0)	(371.0)
Constant	182.0	235.5	96.71	102.1	226.5	229.9	234.5	231.3	231.7

	(334.7)	(337.5)	(386.2)	(386.3)	(328.0)	(326.5)	(338.1)	(330.8)	(331.2)
Observations	6,142,826	6,142,826	6,142,826	6,142,826	6,142,826	6,142,826	6,142,826	6,142,826	6,142,826
R-squared	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065

Source: Data are from a random 40 percent sample of all disabled Medicare beneficiaries, 2006-2014.

Notes: Cohorts by year included beneficiaries 21-64 years of age who were enrolled in fee-for-service Medicare Pars A, B, and D (inpatient, outpatient, and prescriptions benefits) and were alive throughout the calendar year. They exclude patients with cancer diagnoses, end stage renal disease, or who were receiving hospice care. We further restrict sample to 34 U.S. states with information from all three legal sources on enactment and operational dates (Table 3). Opioid receipt is measured by Medicare prescription fills converted to morphine equivalents as in Meara et al. 2016, and summed into an annual measure of milligrams morphine equivalent for each person-year. Models also included indicator variables for each year, 2007 through 2014, age (30-39, 40-49, 50-59, 60-64) with 21-29 as reference. The standard errors shown are adjusted for correlation within states using Huber White Sandwich estimators.*** p<0.01, ** p<0.05, * p<0.1.
See Tables 1 and 2 for an explanation of column headings.

Table 5. Estimated Associations between the Prevalence of Disabled Medicare Beneficiaries with Dispenses at 5 or more Pharmacies and PDMP Enactment and Operational Dates, 2006-2014.

	Enactment								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	Any PDMP	Electronic	PDAPS Enabling	NAMSDL Enactment	PDAPS Operational	NAMSDL Collection Began	Modern System Operational	PDAPS 1.3 User Access	NAMSDL Use Access
PDMP effect (Prob beneficiary >= 5 Pharm*100).	0.0578***	-0.0618***	0.211***	0.209***	0.0118	0.000366	-0.0676***	-0.0292	-0.0304
	(0.0220)	(0.0209)	(0.0233)	(0.0234)	(0.00213)	(0.000215)	(0.0209)	(0.0211)	(0.0209)
Female	0.000909***	0.000909***	0.000910***	0.000910***	0.000909***	0.000909***	0.000909***	0.000909***	0.000909***
	(0.000109)	(0.000109)	(0.000109)	(0.000109)	(0.000109)	(0.000109)	(0.000109)	(0.000109)	(0.000109)
Black race	-0.00263***	-0.00264***	-0.00263***	-0.00263***	-0.00263***	-0.00263***	-0.00264***	-0.00264***	-0.00264***
	(0.000138)	(0.000138)	(0.000138)	(0.000138)	(0.000138)	(0.000138)	(0.000138)	(0.000138)	(0.000138)
Asian, Native, Unknown	-0.00411***	-0.00411***	-0.00411***	-0.00411***	-0.00411***	-0.00411***	-0.00411***	-0.00411***	-0.00411***
	(0.000335)	(0.000335)	(0.000335)	(0.000335)	(0.000335)	(0.000335)	(0.000335)	(0.000335)	(0.000335)
Hispanic ethnicity	-0.00607***	-0.00607***	-0.00607***	-0.00607***	-0.00607***	-0.00607***	-0.00607***	-0.00607***	-0.00607***
	(0.000262)	(0.000262)	(0.000262)	(0.000262)	(0.000262)	(0.000262)	(0.000262)	(0.000262)	(0.000262)
Part D low income subsidy	0.00356***	0.00356***	0.00356***	0.00356***	0.00356***	0.00356***	0.00356***	0.00356***	0.00356***
	(0.000207)	(0.000207)	(0.000207)	(0.000207)	(0.000207)	(0.000207)	(0.000207)	(0.000207)	(0.000207)
Dual eligible for Medicaid	0.00100***	0.00100***	0.00100***	0.00100***	0.00100***	0.00100***	0.00100***	0.00100***	0.00100***
	(0.000163)	(0.000163)	(0.000163)	(0.000163)	(0.000163)	(0.000163)	(0.000163)	(0.000163)	(0.000163)
Depression dx	0.0180***	0.0180***	0.0180***	0.0180***	0.0180***	0.0180***	0.0180***	0.0180***	0.0180***
	(0.000130)	(0.000130)	(0.000130)	(0.000130)	(0.000130)	(0.000130)	(0.000130)	(0.000130)	(0.000130)
Bipolar diagnosis	0.00444***	0.00444***	0.00444***	0.00444***	0.00444***	0.00444***	0.00444***	0.00444***	0.00444***
	(0.000216)	(0.000216)	(0.000216)	(0.000216)	(0.000216)	(0.000216)	(0.000216)	(0.000216)	(0.000216)
Musculoskeletal diagnosis	0.0246***	0.0246***	0.0246***	0.0246***	0.0246***	0.0246***	0.0246***	0.0246***	0.0246***
	(0.000117)	(0.000117)	(0.000117)	(0.000117)	(0.000117)	(0.000117)	(0.000117)	(0.000117)	(0.000117)

Constant	-0.00819***	-0.00783***	-0.00890***	-0.00887***	-0.00797***	-0.00795***	-0.00782***	-0.00788***	-0.00788***
	(0.000348)	(0.000337)	(0.000351)	(0.000351)	(0.000340)	(0.000340)	(0.000337)	(0.000338)	(0.000337)
Observations	6,142,826	6,142,826	6,142,826	6,142,826	6,142,826	6,142,826	6,142,826	6,142,826	6,142,826
R-squared	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	

Source: Data are from 40 percent sample of Medicare beneficiaries aged 21 to 64, 2006-2014.

Notes: Cohorts by year included beneficiaries 21-64 years of age who were enrolled in fee-for-service Medicare Pars A, B, and D (inpatient, outpatient, and prescriptions benefits) and were alive throughout the calendar year. We further restrict sample to 34 U.S. states with information from all three legal sources on enactment and operational dates (Table 1). Opioid receipt from more than 4 pharmacies is measured by Medicare payments for prescriptions filled in more than 4 pharmacies in a calendar year. Models also included indicator variables for each year, 2007 through 2014, age (30-39, 40-49, 50-59, 60-64) with 21-29 as reference. The standard errors shown are adjusted for correlation within states using Huber White Sandwich estimators. *** p<0.01, ** p<0.05, * p<0.1.
See Tables 1 and 2 for an explanation of column headings.