The Reformulation of OxyContin and Availability of Substance Use Treatment Facilities in the United States

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Abstract:
I examine how the substance use treatment sector responded to the abuse-deterrent reformulation of OxyContin, which contributed to a shift from prescription opioid misuse to heroin and synthetic opioids. First, I document a national increase in substance use treatment facilities after the reformulation and a shift toward outpatient-only care. Medication-assisted treatment with buprenorphine and naltrexone grew strongly throughout the first and second waves of the opioid crisis, while opioid treatment programs providing methadone increased relatively modestly after the reformulation. To isolate the role of exposure to OxyContin's reformulation, I use variation in states' pre-reformulation OxyContin misuse rates in a continuous difference-in-differences design. I find that pre-reformulation misuse rates are associated with larger increases in substance use treatment facilities after the reformulation, particularly outpatient-only facilities, with limited evidence misuse rates the availability of medication-assisted treatment services or inpatient care across states. Medicaid expansion under the Affordable Care Act was associated with more substance use treatment facilities and this effect was stronger in states with higher misuse rates, while the expansion of substance use treatment facilities was lower in states with certificate-of-need laws, highlighting the importance of insurance and regulatory barriers in treatment access. Back-of-the envelope estimates suggest the additional SUT facilities averted 2,700-7,800 overdose deaths between 2011 and 2019, corresponding to a value of $36-102 billion.

JEL Classification: I11, I18
KEY WORDS: OxyContin, opioids, substance use, substance use treatment

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1. Introduction

Between 1999 and 2019, nearly 500,000 people died from opioid-involved overdoses, and the 2019 National Survey on Drug Use and Health estimated over 10.1 million people misused opioids and 745,000 used heroin.[1] Economic evaluations estimate the yearly costs of the opioid epidemic to be about $1 trillion (U.S. Congress, Joint Economic Committee, 2017), roughly 5 percent of U.S. gross domestic product. In response to this crisis, governments at all levels and the private sector have taken steps to limit the supply of licit and illicit opioids, reduce demand, and reduce harm from opioid use. In this paper, I examine how the release of the abuse-deterrent formulation of OxyContin, a major supply-side response to reduce prescription opioid misuse, affected substance use treatment (SUT) facilities and provision of SUT services.

The sudden release of OxyContin's abuse-deterrent reformulation in August 2010 is associated with starting the second wave of the opioid crisis as people substituted toward heroin (Cicero et al. 2012; Coplan et al. 2013; Cicero et al, 2015). Initially, this shifted the type of opioids involved in overdose deaths from prescription opioids to heroin (Alpert, Powell, and Pacula, 2018; Evans, Lieber, and Power, 2019), but ultimately increased heroin and semisynthetic opioid deaths as well as polysubstance overdoses as the epidemic continued (Powell and Pacula, 2020). Substitution towards heroin has also been documented by an increase in heroin-related substance use treatment admissions (Alpert, Powell, and Pacula, 2018; Powell and Pacula, 2020) and infectious diseases associated with intravenous drug use (Beheshti, 2019; Powell, Albert, and Pacula, 2019). These effects were concentrated among working-age adults (Alpert, Powell, and Pacula, 2018; DiNardi, 2021; Powell, 2023), leading to reductions in labor supply and income (Park and Powell, 2021). OxyContin's reformulation also had negative spillover effects on crime (Mallat, 2022), children's well-being (Mackenzie-Liu, 2021; Evans et al, 2022; Powell, 2023), and socioeconomic status (Cho et al, 2021; Park and Powell, 2021; Helfin and Sun, 2022). Despite the evidence of OxyContin's reformulation role in worsening the opioid epidemic and related outcomes, little is known about how the SUT sector, which provides

[1] Key Substance Use and Mental Health Indicators in the United States: Results from the 2019 National Survey on Drug Use and Health. U.S. Department of Health and Human Services, Substance Abuse and Mental Health Services Administration. Available at https://www.samhsa.gov/data/sites/default/files/reports/rpt29393/2019NSDUHFFRPDFWHTML/2019NSDUHFFR1PDFW090120.pdf. Accessed April 14, 2025.

supportive services and medication-assisted treatment (MAT) to help people with substance use disorders manage their addiction and reduce overdose risk, responded.

SUT facilities reduce drug overdose deaths (Swensen, 2015), drug-involved emergency room visits (Corredor-Waldron and Currie, 2022), and crime (Fardone et al, 2023), but despite increased need for treatment, the U.S. Department of Health and Human Services (2015) estimated the supply of SUT services was insufficient to meet short-run increases in demand. People with substance use disorder commonly report a lack of treatment providers and programs as a key barrier to treatment. For example, just 12 percent of people with substance use disorders received substance use treatment in 2019 (Substance Abuse and Mental Health Services Administration, 2020a) and 87 percent of people with opioid use disorder (OUD) do not receive MAT (Krawczyk et al, 2022).

Figure 1 shows national trends in SUT facilities and inpatient beds per 100,000 from the 2002-2019 National Survey of Substance Abuse Treatment Services (N-SSATS). Panel A shows SUT facilities declined by 3 percent from 2002 to 2010, coinciding with the rise in prescription opioid misuse in the first wave of the opioid epidemic, but there were on average 8 percent more facilities after OxyContin's reformulation relative to 2010, with more substantial increases at the end of the period. Panel B shows a significant difference in trends in MAT services by medication type. Facilities with opioid treatment programs (OTPs), which are federally certified to provide methadone, were stable until increasing modestly around 2013. In contrast, facilities without OTPs but offering MAT services with buprenorphine or naltrexone grew steadily through the period. Panel C also reveals heterogeneity in trends by service setting. Before OxyContin's reformulation, outpatient-only facilities increased by 5 percent while inpatient facilities declined by 15 percent. After 2010, outpatient growth increased 27 percent while inpatient facilities continued to decline before increasing after 2014. Panel D shows inpatient beds remained mostly flat, with a dip in 2003, and then larger declines in 2017 and 2019.

Together, these trends indicate an expansion of SUT facilities after OxyContin's reformulation, particularly in outpatient care and MAT services. While SUT facilities were on a slight decline before OxyContin's reformulation, they added MAT services, and growth in MAT was even stronger after 2010. In both periods the growth in MAT services was dominated by the

provision of buprenorphine and naltrexone. The national trends also show the increase in SUT facilities was driven by expanding lower-cost outpatient care, while inpatient services declined.

To understand the potential link between SUT facilities and exposure to OxyContin's reformulation, I use a continuous difference-in-differences empirical strategy comparing SUT facility and service availability across states with different pre-reformulation rates of OxyContin misuse before and after the reformulation. States with higher misuse rates are likely to be more exposed to the reformulation, and thus likely to have higher demand for OUD treatment given the links identifying OxyContin's reformulation, misuse rates, and substitution towards heroin and synthetic opioids. I find pre-reformulation misuse rates are associated with more SUT facilities after OxyContin's reformulation. For an average state, SUT facilities increased by 0.8 per 100,000 after OxyContin's abuse-deterrent reformulation was released, and my results show this is driven by an increase in outpatient care facilities. While the national trends show substantial growth in MAT services, I do not find strong evidence exposure to the reformulation affected growth in these services. Event study estimates show a clear trend in buprenorphine and naltrexone provision increasing in states with higher pre-reformulation misuse rates without a clear break around 2010, while estimates for OTPs are noisy. Inpatient services and beds were also higher in states with high misuse rates after the reformulation, but there is not consistent evidence this was associated with higher misuse rates.

In a counterfactual exercise, I estimate there were roughly 700-2,000 more treatment facilities in the average year after OxyContin's reformulation. A rough estimate suggests that without these additional facilities there would have been an additional 2,700-7,800 overdose deaths between 2011 and 2019 with an estimated value of $36-$102 billion. Heterogeneity analyses reveal state expansions of Medicaid coverage are associated with more SUT facilities, and this effect is stronger in states with higher misuse rates, while states with certificate-of-need laws experienced significantly less growth in SUT facilities.

2. Background

2.1 OxyContin

The first wave of the opioid epidemic began with a rise in prescription opioid misuse and overdoses in the late 1990s through the 2000s with the introduction of OxyContin. Introduced to the market in 1996 by Purdue Pharma, OxyContin is an extended-release version of oxycodone

to manage pain. Purdue Pharma pursued an aggressive, targeted marketing strategy for OxyContin (U.S. General Accounting Office 2003; Van Zee, 2009; Kolodny et al, 2015; Alpert et al, 2022), and from 1996 to 2002, OxyContin prescriptions increased nearly 2,200 percent from 316,786 to 7,234,204.[2]

A U.S. General Accounting Office (2003) report on OxyContin's widespread misuse, specifically pointed to OxyContin's safety label as a potential contributor. The safety label warned crushing the tablets could bypass the OxyContin's time-release mechanism to rapidly release oxycodone. This allowed nonmedical users to receive an immediate high by swallowing, snorting, or injecting the crushed contents. In 2004, the National Survey on Drug Use and Health began asking about OxyContin misuse and estimated 3.1 million people had ever used OxyContin non-medically. By 2009, lifetime OxyContin misuse increased 17 percent to 3.6 million people.[3]

Increasing OxyContin misuse led to increases in deaths involving prescription opioids. From 1999 to 2009, overdose deaths involving prescription opioids increased over 250 percent from 2,760 to 9,785.[4] To limit the misuse of OxyContin, the U.S. Food and Drug Administration approved an abuse-deterrent reformulation of OxyContin in April 2010, and Purdue Pharma began shipping the abuse-deterrent reformulation in August. The reformulation, however, was a critical turning point in the opioid crisis, as it had the unintended consequence of shifting nonmedical users toward heroin and increasing the potential need for OUD treatment.

2.2 Substance use treatment facilities

In 2019, there were 15,852 SUT facilities serving nearly 1.5 million clients on a given day in the United States (Substance Abuse and Mental Health Services Administration, 2020b). The type of care and treatment services provided by SUT facilities vary. About 82 percent of facilities offer outpatient services, and nearly all patients, 93 percent, receive outpatient care. Among outpatient facilities, 56 percent offer more intensive services that require a minimum of 9

[2] Author's calculations from Table 2 of U.S. General Accounting Office Report. https://www.gao.gov/assets/gao-04-110.pdf. Accessed April 14, 2025.
[3] Author's calculations from 2004 and 2009 National Survey on Drug Use and Health.
[4] Author's calculations from 1999-2009 Multiple Cause of Death Files CDC WONDER Online Database available from Centers for Disease Control and Prevention, National Center for Health Statistics. Prescription drug overdoses identified using underlying cause of death ICD-10 codes X40-X49 (accidental poisonings), X60-X84 (intentional self-harm), and Y10-Y14 (undetermined intent) and multiple cause of death ICD-10 code: T40.2 (other opioids, excluding methadone).

hours of service per week to help address and manage substance use issues. About one quarter of facilities provide residential care and 6 percent provide inpatient hospital care.

Behavioral health treatments can be effective for treating OUD, but MAT with opioid agonists, either methadone or buprenorphine, are the most effective (Connery, 2015; Wakeman et al, 2020). MAT with the opioid antagonist naltrexone alone is less effective in treating OUD, but it can also be used in combination with opioid agonists (Wakeman et al, 2020). Nearly half of substance use treatment facilities provided some form of MAT in 2019, but methadone can only be dispensed at federally-certified OTPs, which made up less than 11 percent of all facilities.[5] In 2019, 41.6 percent of patients received treatment for substance use disorder received some form of MAT with 11.5 percent receiving buprenorphine, 2.1 percent receiving naltrexone, and 28 percent receiving methadone at an OTP.[6] While methadone cannot be prescribed outside an OTP, buprenorphine and naltrexone can be prescribed by providers outside SUT facilities.[7]

Inpatient-service providing facilities often report operating near or over capacity, indicating unmet need. For example, inpatient utilization rates were 95 percent, and 12 percent of residential and hospital facilities reported being over capacity in 2019 (Substance Abuse and Mental Health Services Administration, 2020b). This is consistent with an undersupply of intensive treatment during the worsening of the opioid epidemic and further documented by the trends in inpatient care and beds in Figure 1.

There may be significant barriers to expanding services or opening new SUT facilities due to capital and labor constraints, regulatory burdens, and community opposition. Despite 90 percent of SUT facilities being privately-owned in 2019, nearly half relied on some form of public funding (Substance Abuse and Mental Health Services Administration, 2020b).

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[5] National Survey of Substance Abuse Treatment Services (N-SSATS): 2019, Data on Substance Abuse Treatment Facilities, Table 2.3 https://www.samhsa.gov/data/report/national-survey-substance-abuse-treatment-services-n-ssats-2019-data-substance-abuse. Accessed April 14, 2025.

[6] Author's calculations from National Survey of Substance Abuse Treatment Services (N-SSATS): 2019, Data on Substance Abuse Treatment Facilities, Table 3.2 https://www.samhsa.gov/data/report/national-survey-substance-abuse-treatment-services-n-ssats-2019-data-substance-abuse. Accessed April 14, 2025.

[7] Buprenorphine could be prescribed in outpatient settings by providers authorized with a DATA 2000 waiver from the U.S. Drug Enforcement Agency, and this requirement was removed in 2023. In contrast, naltrexone, which is not a controlled substance, had no prescribing restrictions.

Workforce shortages are also commonly cited as a limiting factor in SUT facilities' ability to expand or open, as they face issues with recruiting and retaining workers (Ryan, Murphy, and Krom, 2012).

Regulatory barriers vary by facility type. Outpatient services are generally unregulated, but OTPs must meet strict federal requirements to dispense methadone including accreditation, registration with the U.S. Drug Enforcement Agency, and periodic certification renewal. More broadly, Jackson et al (2020) identified 89 different state-level regulations across 47 states that may further complicate expanding SUT facilities, such as pharmacy licensure, adherence to pharmacy regulations, and zoning laws. Certificate-of-need laws that require providers to show economic necessity have received most attention, although evidence on the effects of these laws on SUT facilities is somewhat mixed (Noh and Brown, 2018; Bailey, Lu, and Vogt, 2022). Overall, many of the state-level regulations are not recommended as best practices by the U.S. Substance Abuse and Mental Health Services Administration (Jackson et al, 2020) and may further limit the abilities of SATs to expand services. At local levels, public resistance is another barrier to SUT facilities' expansion, often driven by stigma (Cheetham et al, 2022) and concerns about crime (Takahashi and Dear, 1997). Service availability may also reflect local sociodemographic characteristics such as racial and ethnic composition (Goedel et al, 2020; DiNardi, Swann, and Kim, 2022; Jehan et al, 2024), income (Horn, Joshi, and Maclean, 2021; Jehan et al, 2024), and collaborative efforts between local government and relevant stakeholders (Swann, DiNardi, and Schreiber, 2022).

3. Data

Following Alpert *et al* (2018), I combine the 2004-2009 non-medical OxyContin use rates from the National Survey on Drug Use and Health to create a state-level measure of pre-reformulation exposure to OxyContin's reformulation. Non-medical use in the National Survey on Drug Use and Health is defined as use "only for the experience or feeling it caused" or use by people not originally prescribed the medication. This measure of OxyContin misuse is commonly used in the OxyContin reformulation literature across a variety of outcomes such as heroin and opioid-involved mortality (Alpert et al, 2018; Powell and Pacula, 2021), lifetime heroin use among adolescents (DiNardi, 2021), hepatitis (Beheshti, 2019; Powell, Alpert, and Pacula, 2019), and suicide (Powell, 2023). Additionally, this measure is associated with other

proxies for misuse such as legal retail shipments of oxycodone from the U.S. Drug Enforcement Agency's Automation of Reports and Consolidated Orders System and prescriptions reported in the Medical Expenditure Panel Survey (Alpert et al, 2018).

I collect annual counts of substance use treatment facilities and inpatient beds in each state from the 2002-2019 National Survey of Substance Use Treatment Services (N-SSATS). While the N-SSATS is a voluntary survey of substance use treatment facilities, the response rate is a near census of SUT facilities, and the N-SSATS collects information on service provision such as whether the facility operates an OTP, provides MAT, offers outpatient or inpatient services, and inpatient beds. Facility data is available in every year, but information on inpatient beds was not collected in 2014, 2016, or 2018.[8] I convert state-by-year counts of treatment facilities and inpatient beds to rates per 100,000 population using population estimates from the U.S. National Cancer Institute's Surveillance, Epidemiology, and End Results Program. More specifically, I fix states' population estimates in 2010 so changes in rates per 100,000 are driven by changes in the number of facilities and not affected by yearly variation in state population estimates.[9]

Table 1 presents population-weighted summary statistics on SUT facilities and OxyContin misuse rates across states, comparing the periods before (2002-2010) and after (2011-2019) the release of abuse-deterrent OxyContin. The average misuse rate was 0.57 percent, ranging from 0.26 percent in Illinois to 1.15 percent in Rhode Island. High misuse states (at or above the median OxyContin misuse rate) had an average misuse rate of 0.84 percent while low misuse states (below the median OxyContin misuse rate) had an average misuse rate of 0.45 percent. Nationally, SUT facilities per 100,000 rose from 4.33 before the reformulation to 4.59 after, a 6 percent increase. This growth was more pronounced in high misuse states, increasing 13 percent from 4.74 to 5.35, compared to a 2 percent increase from 4.16 to 4.25 in low misuse states. MAT services with buprenorphine or naltrexone roughly doubled, with larger gains in high misuse states. Outpatient-only facilities also expanded, particularly in high misuse states, while inpatient-only facilities were flat nationally due to a slight decrease in low misuse states and slight increase in high misuse states. Facilities offering both outpatient and inpatient

[8] Inpatient beds are misreported for Rhode Island in 2015, so I drop this observation from the analysis.
[9] Results are robust to using yearly population estimates to calculate rates. Results are available by request.

services declined in all states. The number of inpatient beds was roughly constant nationally, reflecting a decline in low misuse states and modest increase high misuse states. Overall, the summary statistics indicate greater expansion of SUT facilities and services in high misuse states following OxyContin's reformulation.

4. Methods

I estimate an event study specification following Powell and Pacula (2021) to estimate the relationship between OxyContin misuse prior to the reformulation and SUT facilities and services per 100,000 in each year, conditional on general pain reliever misuse to control for broader changes related to general prescription opioid misuse across states. To capture the dynamics between OxyContin misuse and treatment facility availability, the event study specification takes the following form:

$$y_{st} = \beta_0 + \sum_{t=2002, t\neq 2010}^{2019} \beta_t \left(\mathrm{K}_t \times OxyMisuse_s^{pre}\right) + \sum_{t=2002, t\neq 2010}^{2019} \theta_t \left(\mathrm{K}_t \times PainRelieverMisuse_s^{pre}\right) + \boldsymbol{\lambda_s} + \boldsymbol{\delta_t} + \epsilon_{st} \quad (1),$$

where y_{st} is the number of SUT facilities or inpatient beds per 100,000 in state s in year t. K_t is an indicator for year t and $OxyMisuse_s^{pre}$ is the pre-reformulation (2004-2009) rate of OxyContin misuse in state s. State fixed effects, $\boldsymbol{\lambda_s}$, control for time-invariant differences between states and year fixed effects, $\boldsymbol{\delta_t}$, control for yearly differences common to all states. I weight the regressions by state population using estimates from the U.S. National Cancer Institute's Surveillance, Epidemiology, and End Results program and cluster the standard errors at the state level. I separately estimate equation (1) for all facilities, OTPs, facilities that provide MAT with buprenorphine or naltrexone, service setting (outpatient only, inpatient only, or both outpatient and inpatient services provided), and inpatient beds.

β_t represents the effect of a one percentage point increase in the OxyContin misuse rate on SUT facilities and services per 100,000, relative to 2010, conditional pain reliever misuse. Small and statistically insignificant pre-period coefficients help provide evidence of the parallel trends assumption that the rate of SUT facilities and services evolved similarly across states with different rates of OxyContin misuse prior to the reformulation. Post-period coefficients identify any dynamic effects of the OxyContin reformulation on SUT facilities per 100,000. Recent work by Callaway, Goodman-Bacon, and Sant'Anna (2024) show difference-in-difference designs with continuous treatment require a stronger parallel trends assumption. In this setting, the

stronger assumption requires the effect of OxyContin's reformulation would be the same in states with high OxyContin misuse rates had they "received" a lower misuse rate.

To provide a summary measure, I estimate the following equation separately for each of the outcomes:

$$y_{st} = \beta_0 + \beta_1 I(Year \geq 2011) \times OxyMisuse_s^{pre} + \beta_2 I(Year \geq 2011) \times PainRelieverMisuse_s^{pre} + \boldsymbol{\lambda_s} + \boldsymbol{\delta_t} + \epsilon_{st} \quad (2)$$

where β_1 reflects the average change in SUT facilities or inpatient beds per 100,000 after OxyContin's reformulation from a 1 percentage point increase in the OxyContin misuse rate.

5. Results

4.1 Event study estimates

Figure 2 shows the event study estimates and 95 percent confidence intervals for all SUT facilities. The pre-period estimates for all facilities are individually statistically insignificant but I fail to reject joint significance (p-value = 0.08). While this may be evidence of an upward trend, it is less apparent in the years immediately preceding OxyContin's reformulation. After 2010, the point estimates indicate SUT facilities increased and, while the confidence intervals overlap, the effects are generally larger each year.

Figure 3 shows event study estimates by MAT provision. For OTPs (Panel A), the pre-period coefficients appear to trend upward. While they are mostly individually insignificant, the coefficients are jointly significant (p-value = 0.03), indicating states with higher misuse rates were experiencing growth in OTPs prior to the reformulation. After 2010, there is no discernable shift or change in the trajectory of OTPs, and while the point estimates rise at the end of the sample, they are not statistically significant. In contrast, non-OTP facilities with MAT (Panel B) show an upward trajectory throughout the period, consistent with SUT facilities responding to the growth in prescription opioid misuse throughout the 2000s and buprenorphine's approval to treat OUD beginning in 2002.

Together, Figures 2 and 3 suggest suggests that during the first wave of the opioid crisis, SUT facilities expanded MAT services with buprenorphine and naltrexone rather than opening new facilities. After OxyContin's reformulation, SUT facilities increased, with continued growth in MAT provision likely reflecting expansion of these services within existing facilities and new

facilities preferring to offer MAT with buprenorphine and naltrexone rather than going through the accreditation and certification process to dispense methadone as an OTP.

Finally, Figure 4 shows the event study estimates by service setting and inpatient beds. In Panel A, outpatient-only facilities show no significant pre-period differences across states with a joint p-value of 0.40, but all post-reformulation coefficients are statistically significant and generally increase over time, indicating outpatient facilities primarily drove growth in SUT facilities. Panel B shows some statistically significant pre-period estimates for inpatient-only facilities, but they are not jointly significant (p-value = 0.16). After 2010, estimates are slightly positive, but insignificant. Estimates for facilities with both outpatient and inpatient services (Panel C) show now pre-period differences or clear evidence of a change after OxyContin's reformulation. Finally, for inpatient beds (Panel D), there is some pre-period variation across states but it is not jointly significant (p-value = 0.38). There is some evidence of an increase in inpatient beds after OxyContin's reformulation in 2015, 2017, and 2019, but it is difficult to draw a strong conclusion because of the limited post-reformulation observations.

4.2 Summary estimates

Table 2 presents the estimated effect from the interaction of pre-reformulation misuse and the post-2010 indicator on SUT facilities and inpatient beds from equation (2). To interpret these as the average effect, I scale the estimates by the population-weighted average OxyContin misuse rate (0.57). In column 1, there is a statistically significant 0.86 average increase in SUT facilities per 100,000, a 20 percent increase relative to 2010. In line with the event study estimates, I do not find a statistically significant increase in OTPs (column 2). Non-OTPs offering MAT (column 3) show a significant increase, reflecting the upward trend found from the event study. Columns 4-6 show the increase in SUT facilities in column (1) was driven by outpatient-only facilities. At the mean misuse rate, this implies an average increase of 0.77 per 100,000. Finally, column 7 shows a statistically significant average increase of 7.3 inpatient beds per 100,000 for the average state.

6. Heterogeneity

5.1 Certificate-of-need laws

To test whether state-level certificate-of-need laws limit SATs' ability to expand after OxyContin's reformulation, I add two variables to equation (2) that interact the OxyContin misuse and pain reliever misuse treatment variables with an indicator for whether a state had a CON law in place throughout the sample period. Data on state certificate-of-need laws come from Bailey, Lu, and Vogt (2022). From 2002-2019, substance use treatment certificate-of-need laws were in place in 21 states, 26 states did not have a certificate-of-need law in place, and four states added or removed certificate-of-need laws. I remove the four states that changed their certificate-of-need law status during the sample period so that estimates are not biased by comparing states with CON laws to states that change their CON law status during the period.[10]

States with certificate-of-need laws had a higher average pre-reformulation OxyContin misuse rate (0.65) compared to states without the law (0.49) and thus potentially more exposed to OxyContin's reformulation. The point estimates in Table 3 show SUT facilities increased less in states with certificate-of-need laws after OxyContin's reformulation. While this difference is not statistically significant, the difference in point estimates is large as certificate-of-need laws reduced the effect of exposure to OxyContin's reformulation by nearly 72 percent. Using the average OxyContin misuse rates, these estimates imply SUT facilities per 100,000 increased by 0.34 (8 percent relative to 2010) in states with certificate-of-need laws and 0.92 (16 percent relative to 2010) in states without these regulations.

5.2 Medicaid expansion

About 68 percent of facilities accepted Medicaid in 2019, up from 61 percent in 2013 before the first states expanded Medicaid coverage as part of the Patient Protection and Affordable Care Act in 2014.[11] The expansion of Medicaid coverage increased substance use treatment admissions (Grooms and Ortega, 2019; Saloner and Maclean, 2020), particularly in

[10] The four dropped states are Connecticut (removed in 2006; reinstated in 2007), Kentucky (enacted in 2007), New Hampshire (removed in 2016) and Washington, D.C. (removed in 2007; reinstated in 2008).

[11] National Survey of Substance Abuse Treatment Services (N-SSATS): 2019, Data on Substance Abuse Treatment Facilities, Table 4.22b https://www.samhsa.gov/data/report/national-survey-substance-abuse-treatment-services-n-ssats-2019-data-substance-abuse. National Survey of Substance Abuse Treatment Services (N-SSATS): 2013, Data on Substance Abuse Treatment Facilities, Table 6.18b https://www.samhsa.gov/data/sites/default/files/2013_nssats_rpt.pdf. Accessed April 14, 2025.

intensive outpatient programs and MAT services for OUD (Saloner and Maclean, 2020). Grooms and Ortega (2019) do not find an effect of the Medicaid expansions on the number of SUT facilities, although their data only extends until 2 years after the first expansion of Medicaid coverage in 2014. OxyContin misuse rates are similar across expanding (0.55) and non-expanding states (0.59). States expanded Medicaid coverage at different times which can bias estimates if states that already expanded Medicaid are used as controls for states that expand Medicaid later (Goodman-Bacon, 2021). I augment equation (2) to include an indicator for whether a state has expanded Medicaid and interact it with the OxyContin misuse and pain reliever misuse variables. To deal with the issue of the staggered timing of Medicaid expansions, I use the "stacked" difference-in-differences method with never expanding states and not-yet-expanded states as controls.

Table 4 presents the estimates from this exercise. First, states that expanded Medicaid coverage generally had more SUT facilities but fewer inpatient beds. These effects are not statistically significant, except for the effect on outpatient-only facilities. States that expanded Medicaid and had higher rates of OxyContin misuse also had statistically significant increases in SUT facilities, again driven by outpatient-only facilities. The implied effect on SUT facilities per 100,000 using average OxyContin misuse rates is 2.38 for Medicaid expanding states and 0.65 for non-expanding states.[12] This diverges from prior work which do not find evidence SUT facilities increased after Medicaid expansion, perhaps due to a shorter time period studied,[13] but it is consistent with SUT facilities responding to additional OUD treatment demand from expanded Medicaid coverage. These estimates, however, should be interpreted with some caution as states may have expanded Medicaid coverage partly in response to the worsening opioid epidemic.

7. Robustness to alternative specifications

Appendix Table A1 shows estimates from alternative specifications to examine the robustness of the main estimates in Table 2. Panel A presents estimates excluding pain reliever

[12] For Medicaid expansion states this is calculated as $(0.55 \times 1.11) + (0.55 \times 1.11) + 1.16 = 2.38$. For non-expansion states this is calculated as $(0.59 \times 1.11) = 0.65$.

[13] Grooms and Ortega (2019) use data from 2010-2016 and their sample only includes states that expanded Medicaid coverage on January 1, 2014 and states that did not expand Medicaid by December 31, 2015. My sample runs through 2019, capturing up to 6 years of Medicaid expansion for states expanding Medicaid coverage in 2014 and effects of states that expanded coverage after 2014.

misuse from equation (2). These estimates are similar to the main estimates in Table 2, but slightly smaller in magnitude. One may be concerned about other changes in substance use across states around the time of OxyContin's reformulation that may also affect SUT facilities and services. I calculate state averages of heavy drinking in the past 30 days, lifetime cannabis use, and lifetime cocaine use from the 2004-2009 National Survey on Drug Use and Health, interact these variables with an indicator for 2011 or later, and re-estimate equation (2) with these additional interactions. The estimated effects including these additional controls in Panel B are similar in magnitude and statistical significance to the main estimates in Table 2.

Two-way fixed effects in this setting may suffer from both selection bias and complex weighting schemes (Callaway, Goodman-Bacon, and Sant'anna, 2024). Assuming strong parallel trends eliminates selection bias but does not fix issues with weighting. For example, the scaled effects described earlier, which multiply the two-way fixed effect estimates by the average OxyContin misuse rate, attach positive (negative) weight to observations above (below) the mean misuse rate. To investigate this issue, I estimate a simple difference in the pre and post period means on the pre-reformulation misuse rate (Panel C) and, to capture potential nonlinearities, estimate this relationship using a cubic B-spline and one knot (Panel D) (Callaway, Goodman-Bacon, and Sant'anna, 2024).

The estimates in Panel C, which weights states equally, are similar to those in Panel A, which are population-weighted, except for the effect on inpatient beds where the estimate in Panel C is 45 percent smaller. This discrepancy arises because OxyContin misuse rates are lower in higher population states, thus receive less weight in the regression estimates for Panel A, and the estimated relationship between the change in inpatient beds and misuse rates is higher in these states (14.8) while in high misuse states with lower populations the linear estimate is flatter (2.6).

Panel D reports the average treatment effect from the non-parametric regressions. Discrepancies between the estimates in Panel A (evaluated at the mean misuse rate) and Panel D could be driven by two-way fixed effects weighting or nonlinearities, but because the estimates in Panel C are estimated from simple differences in pre- and post-period means, they are not biased by two-way fixed effects weights. Thus, large differences between the estimates in Panel C (evaluated at the mean misuse rate) and nonparametric estimates in Panel D would suggest

potential bias due to nonlinearities in the relationship between SUT facilities and pre-reformulation OxyContin misuse rates. Appendix Figure A2 plots the estimated effects and 95 percent confidence intervals from the nonparametric specification across the range of misuse rates and the simple linear relationship from the estimates in Panel C. Focusing on the magnitudes for SUT facilities and outpatient facilities, these estimates are slightly smaller, 0.66 and 0.50, respectively, are very close to the estimates in Panel C when estimated at the mean OxyContin misuse rate, and the plots show the effects are relatively linear. The estimated effect for inpatient beds is much smaller at 0.51 while the estimate in Panel C evaluated at the mean misuse rate is 3.25. The plotted estimates for inpatient beds in Appendix Figure A2 suggest this divergence is due to the strong nonlinear relationship between inpatient beds and OxyContin misuse rates.

Finally, I use the 2004-2009 average state retail shipments of oxycodone in morphine milligram equivalents per 100,000 from the U.S. Drug Enforcement Agency's Automation of Reports and Consolidated Orders System as an alternative measure of measure of exposure to the OxyContin reformulation. Retail shipments per capita are significantly correlated with the measure of OxyContin misuse, but retail shipments of oxycodone reflect both medical and non-medical use of OxyContin. While the magnitudes of the estimates in Panel E are not directly comparable to those in Table 2 or other panels in this table, they are similar in direction, but less precise, likely due to conflating medical and non-medical use in the retail shipments.

8. Discussion

The opioid crisis in the United States began in the late 1990s with an increase in prescription opioid use, particularly from the introduction of OxyContin. By the mid-2000s, concerns over misuse grew as opioid use disorder and opioid-involved mortality rose, and in 2010, Purdue Pharma released an abuse-deterrent reformulation of OxyContin intended to reduce its misuse. Rather than curbing the crisis, the reformulation worsened it, as people substituted toward heroin and synthetic opioids, leading to further increases in overdose deaths.

This shift towards riskier opioids increased the need for substance use treatment. During the first wave of the opioid epidemic, there was little change in the number of SUT facilities, but facilities increasingly added MAT services with buprenorphine and naltrexone while OTPs providing methadone were roughly constant. After OxyContin's reformulation in 2010, there

was an increase in the number of SUT facilities, driven by an increase in outpatient-only care, while both inpatient care facilities and inpatient beds decreased. Growth in MAT services continued similarly after 2010, and while there were 45 percent more OTPs after 2010, this increase was significantly less than the 130 percent increase in buprenorphine and naltrexone MAT availability in facilities without an OTP. As a share of total MAT provision, buprenorphine and naltrexone increased from about 59 percent in 2002 to nearly 79 percent by 2019. These trends demonstrate a general shift from relatively costly inpatient care and methadone provision to lower-barrier outpatient care and MAT with buprenorphine and naltrexone.

Using a continuous difference-in-differences empirical strategy, I show exposure to OxyContin's reformulation is associated with changes in the SUT sector as states with higher pre-reformulation misuse rates experienced larger increases in SUT facilities, primarily driven by outpatient-only facilities. While states with higher rates of misuse also had more inpatient services and beds on average after the reformulation, the evidence linking higher misuse rates is weaker. Similarly, I do not find evidence exposure to the reformulation led to changes in OTPs or non-OTPs providing MAT services via buprenorphine or naltrexone. SUT facilities expanded more in states that expanded Medicaid coverage under the Affordable Care Act, highlighting important interactions between insurance coverage and the SUT sector.

While my results cannot speak to all factors that may hinder expansion of SUT facilities and services, they suggest regulatory burdens played a role. I find states with certificate-of-need laws had higher pre-reformulation OxyContin misuse rates, but higher misuse rates had less of an effect on SUT expansion in these states after OxyContin's reformulation. I do not find strong evidence suggesting OTPs increased in states with higher rates of OxyContin misuse after its reformulation. This could reflect limited ability to expand OTPs due to their strict certification requirements. Future work could investigate whether this was a limiting factor or reflected the general trend towards less-restrictive MAT via buprenorphine and naltrexone. More broadly, these results highlight the need for additional research into factors that may have enabled or restricted the ability of SUT facilities to expand.

To further understand the potential impact of the additional SUT facilities, I conduct an exercise to estimate the potential number of lives saved by these facilities. I begin by estimating three counterfactuals for the number of SUT facilities following the OxyContin reformulation.

First, I estimate a simple linear trend from 2002 to 2010 and use this to predict SUT facilities per 100,000 in the 2011 to 2019 period. I also use the event study estimates to estimate two counterfactual settings: (1) the U.S. was lightly exposed to the OxyContin reformulation by plugging in the lowest OxyContin misuse rate (0.26) and (2) the U.S. was "unexposed" to the OxyContin reformulation by setting the event study estimates to zero. I then use these estimates per 100,000 to calculate the overall number of SUT facilities in each year. Figure A1 shows per capita SUT facilities and estimated counterfactuals, and Table A2 presents the differences between the observed and counterfactual counts in each year. On average, the difference between the observed and counterfactual facility count is 711 (linear counterfactual), 1,076 (OxyContin reformulation effect from lowest misuse rate), and 2,025 (no effect on SUT facilities from OxyContin reformulation).

Swensen (2015) estimates an additional SUT facility is associated with 0.43 fewer drug and alcohol overdose deaths. Extrapolating across the counterfactual facility counts, the opening of SUT facilities in response to the effects of OxyContin's reformulation averted about 2,700-7,800 deaths. Using the U.S. Department of Health and Human Service's central estimate for the value of a statistical life ($13 million in 2023 dollars), this results in an estimated value of $36-$102 billion. This likely understates the overall value of additional SUT facilities since they do not capture other direct and indirect effects of access to substance use treatment. Additionally, MAT provision of buprenorphine or naltrexone in non-OTP facilities continued to grow, and healthcare providers may have also responded by receiving waivers from the U.S. Drug Enforcement Agency to prescribe buprenorphine in private practice settings. Given buprenorphine's similar effectiveness to methadone, these changes likely averted additional opioid deaths and deserve attention.

While these results suggest significant benefits from the expansion of SUT facilities after OxyContin's reformulation, the estimated lives saved represent less than 2.5 percent of the approximately 320,000 opioid-involved deaths between 2011 and 2019.[14] This underscores that

[14] Author's calculations from 2011-2019 Multiple Cause of Death Files CDC WONDER Online Database available from Centers for Disease Control and Prevention, National Center for Health Statistics. Prescription drug overdoses identified using underlying cause of death ICD-10 codes X40-X49 (accidental poisonings), X60-X84 (intentional self-harm), and Y10-Y14 (undetermined intent) and multiple cause of death ICD-10 code: T40.0 (opium), T40.1 (heroin), T40.2 (other opioids, excluding methadone), T40.3 (Methadone), T40.4 (other synthetic narcotics), T40.6 (other and unspecified narcotics).

expanding treatment access, while important, is one piece in the broader public health response necessary to address the opioid epidemic. OxyContin's reformulation was, itself, a broad response to worsening prescription opioid misuse, and at the state-level, many policies were implemented to restrict access to opioids and reduce harm such as prescription drug monitoring programs, naloxone access laws, and other initiatives with varying levels of success (Maclean et al, 2021). Future research should examine how state policy environments evolved after the reformulation, including whether states increased adoption of opioid-related policies and how such policies interact with treatment supply and access. A more comprehensive understanding of the relationship between policy, regulation, and treatment infrastructure is critical for addressing the continuing opioid epidemic.

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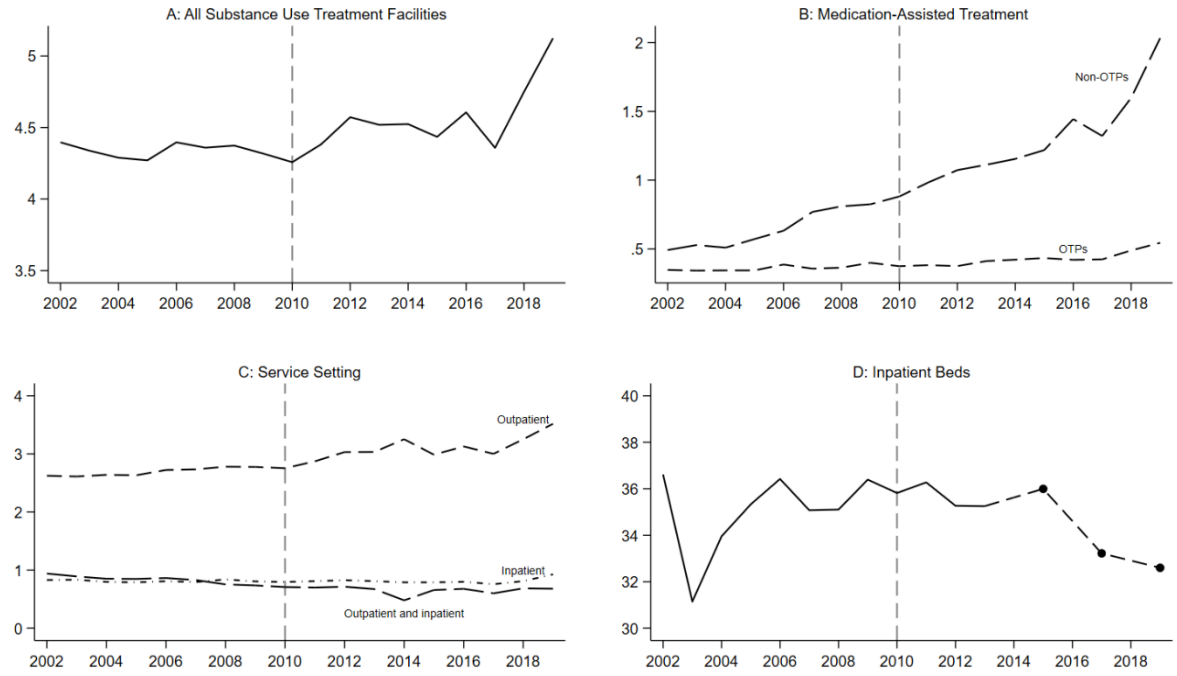
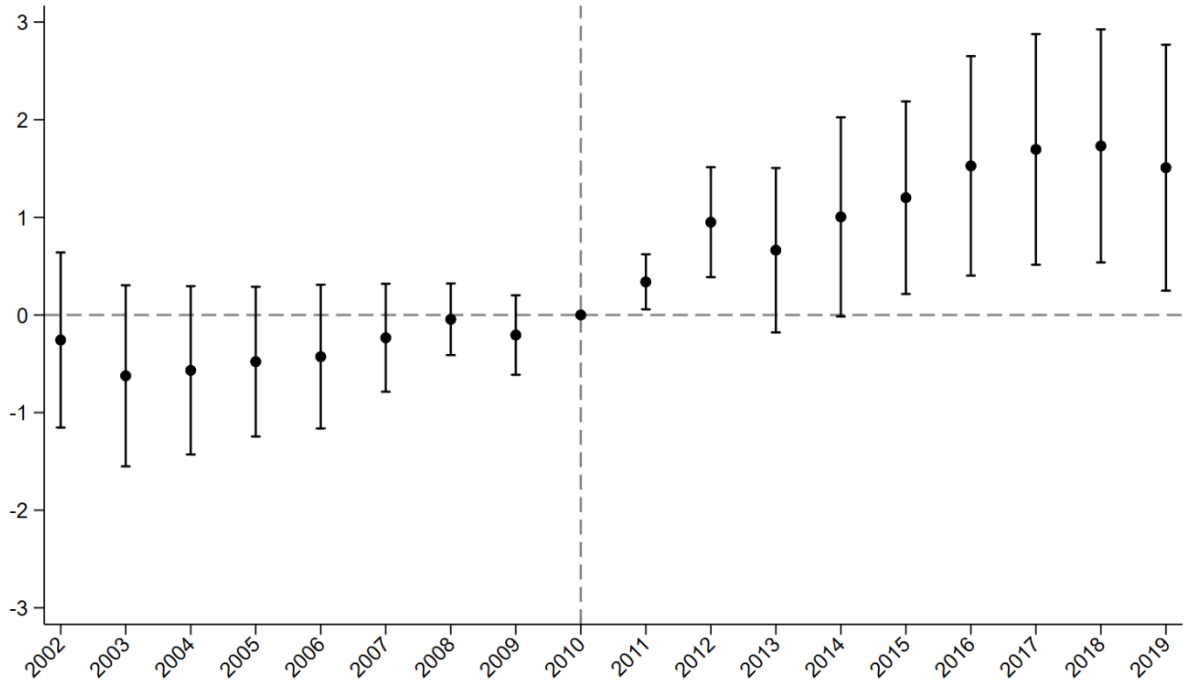
Figures

Figure 1: Substance abuse treatment facilities and beds per 100,000 population, 2002-2019



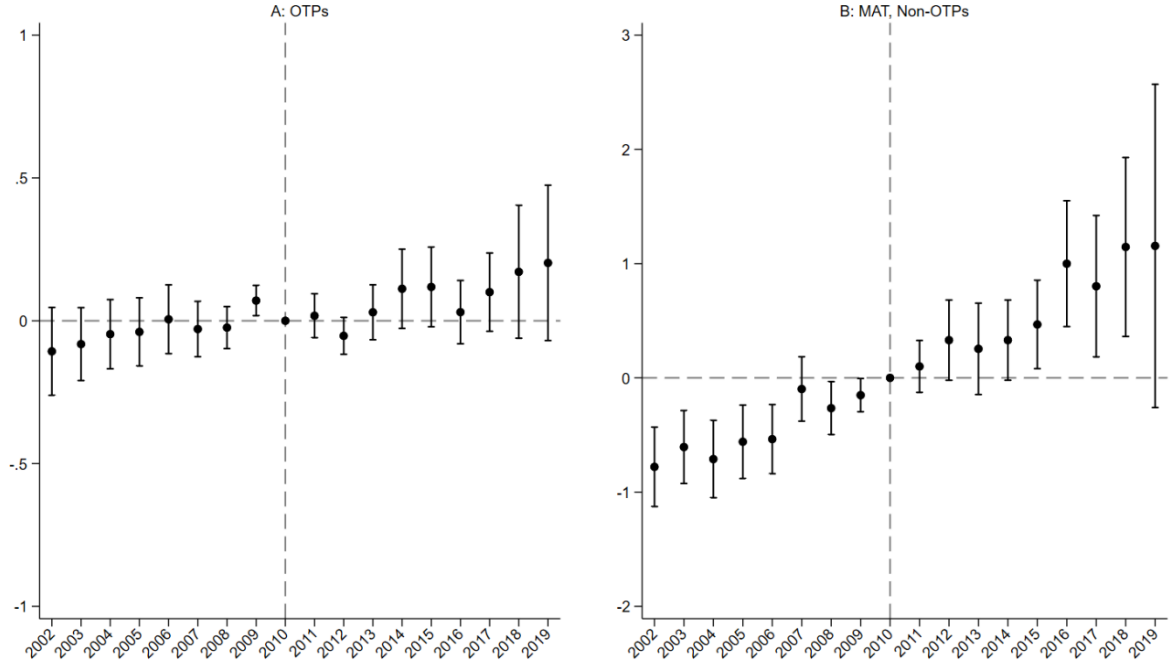
Notes: Number of substance use treatment facilities and inpatient beds from 2002-2019 U.S. National Survey of Substance Abuse Treatment Services. Data for inpatient beds was not collected in 2014, 2016, or 2018. Population estimates from 2010 U.S. National Cancer Institute's Surveillance, Epidemiology, and End Results Program. OTPs: Opioid Treatment Programs. Dashed line in 2010 denotes year of OxyContin's reformulation.

Figure 2: Event study estimates: SUT facilities per 100,000



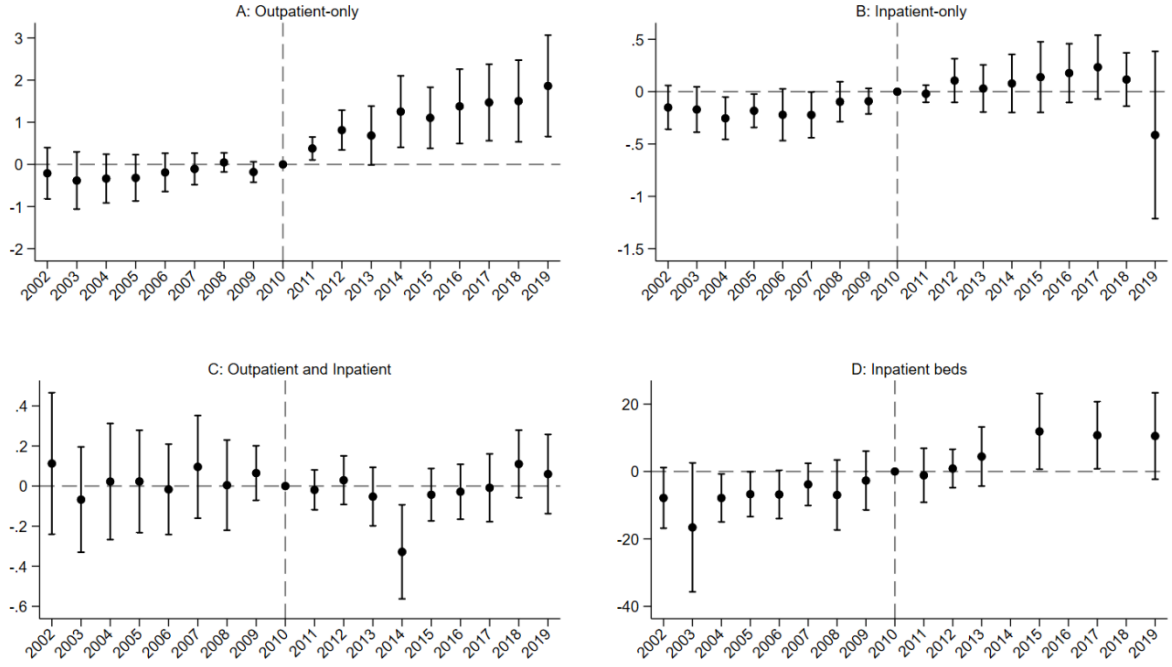
Notes: Event study estimates and 95% confidence intervals from the interaction of $OxyMisuse_s^{pre}$ with year indicators. Standard errors clustered at the state level. $OxyMisuse_s^{pre}$ is the state-level rate of OxyContin misuse estimated from the 2004-2009 National Survey on Drug Use and Health. The regression includes interactions with state-level pain reliever misuse rates interacted with year indicators, state fixed effects, and year fixed effects and is weighted by state population. Data on the number of substance use treatment facilities from the 2002-2019 National Survey of Substance Abuse Treatment Services. Population data from the U.S. National Cancer Institute's Surveillance, Epidemiology, and End Results Program. Dashed line in 2010 denotes year of OxyContin's reformulation.

Figure 3: Event study estimates by MAT facility type, per 100,000



Notes: Event study estimates and 95% confidence intervals from the interaction of $OxyMisuse_s^{pre}$ with year indicators. Standard errors clustered at the state level. $OxyMisuse_s^{pre}$ is the state-level rate of OxyContin misuse estimated from the 2004-2009 National Survey on Drug Use and Health. The regressions include interactions with state-level pain reliever misuse rates interacted with year indicators, state fixed effects, and year fixed effects and is weighted by state population. Data on the number of substance use treatment facilities from the 2002-2019 National Survey of Substance Abuse Treatment Services. Population data from the U.S. National Cancer Institute's Surveillance, Epidemiology, and End Results Program. Dashed line in 2010 denotes year of OxyContin's reformulation.

Figure 4: Event study estimates by facility service setting and beds, per 100,000



Notes: Event study estimates and 95% confidence intervals from the interaction of $OxyMisuse_s^{pre}$ with year indicators. Standard errors clustered at the state level. $OxyMisuse_s^{pre}$ is the state-level rate of OxyContin misuse estimated from the 2004-2009 National Survey on Drug Use and Health. The regressions include interactions with state-level pain reliever misuse rates interacted with year indicators, state fixed effects, and year fixed effects and is weighted by state population. Data on the number of substance use treatment facilities and inpatient beds from the 2002-2019 National Survey of Substance Abuse Treatment Services. Population data from the U.S. National Cancer Institute's Surveillance, Epidemiology, and End Results Program. Dashed line in 2010 denotes year of OxyContin's reformulation.

Tables

Table 1: Summary statistics

	All states		States below median OxyContin misuse rate		States at or above median OxyContin misuse rate	
OxyContin misuse rate (percent, 2004-2009)	0.57 (0.22)		0.45 (0.13)		0.84 (0.12)	
Outcomes	2002-2010	2011-2019	2002-2010	2011-2019	2002-2010	2011-2019
Substance Use Treatment Facilities	4.33 (1.61)	4.59 (1.85)	4.16 (1.47)	4.25 (1.58)	4.74 (1.85)	5.35 (2.17)
Opioid Treatment Programs (OTPs)	0.36 (0.26)	0.43 (0.26)	0.38 (0.24)	0.44 (0.22)	0.32 (0.28)	0.42 (0.33)
Medication-Assisted Treatment Services, without an OTP	0.67 (0.45)	1.33 (0.75)	0.62 (0.39)	1.21 (0.67)	0.78 (0.55)	1.59 (0.87)
Outpatient only	2.70 (1.25)	3.12 (1.56)	2.56 (1.14)	2.84 (1.34)	3.02 (1.44)	3.75 (1.84)
Inpatient only	0.81 (0.45)	0.81 (0.44)	0.82 (0.45)	0.81 (0.42)	0.78 (0.44)	0.82 (0.46)
Outpatient and Inpatient services	0.82 (0.36)	0.65 (0.30)	0.77 (0.32)	0.59 (0.27)	0.94 (0.42)	0.76 (0.33)
Inpatient beds	35.1 (15.3)	34.8 (14.5)	36.3 (16.3)	34.7 (14.3)	32.4 (12.2)	35.0 (15.1)

Notes: Population-weighted means with standard deviation in parentheses. OxyContin misuse rate from the 2004-2009 National Survey on Drug Use and Health. Substance use treatment facility counts and inpatient bed counts from 2002-2019 National Survey of Substance Abuse Treatment Services. Population estimates from U.S. National Cancer Institute Surveillance, Epidemiology, and End Results program.

Table 2: Effect of 2010 OxyContin Reformulation on SUT facilities and inpatient beds per 100,000

	All	Opioid Treatment Programs	Medication-assisted treatment (non-OTP)	Outpatient only	Inpatient only	Outpatient and inpatient services	Inpatient beds
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OxyContin effect	1.50***	0.11	1.03***	1.35***	0.20	-0.06	12.8**
	(0.56)	(0.07)	(0.25)	(0.39)	(0.13)	(0.11)	(5.76)
Observations	918	918	918	918	918	918	763

Notes: Standard errors clustered at state level in parentheses. The OxyContin reformulation effect is the coefficient from an interaction between the state 2004-2009 OxyContin misuse rate and an indicator for year 2011 or later. All regressions include an interaction between the state 2004-2009 pain reliever misuse rate and an indicator for year 2011 or later, state fixed effects, and year fixed effects, and weighted by state population.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 3: Effect of 2010 OxyContin Reformulation on SUT facilities and inpatient beds per 100,000 by certificate-of-need status

	All	Opioid Treatment Programs	Medication - assisted treatment (non-OTP)	Outpatient only	Inpatient only	Outpatient and inpatient services	Inpatient beds
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OxyContin effect	1.87**	0.10	0.85**	1.72***	0.24	-0.09	14.8**
	(0.76)	(0.07)	(0.36)	(0.51)	(0.20)	(0.12)	(6.51)
(OxyContin effect) x (Certificate-of-need law)	-1.34	-0.01	0.77	-1.29*	-0.09	0.01	-12.85
	(0.98)	(0.27)	(0.51)	(0.77)	(0.25)	(0.24)	(8.67)
Observations	846	846	846	846	846	846	703

Notes: Standard errors clustered at state level in parentheses. The OxyContin reformulation effect is the coefficient from an interaction between the state 2004-2009 OxyContin misuse rate and an indicator for year 2011 or later. All regressions include an interaction between the state 2004-2009 pain reliever misuse rate and an indicator for year 2011 or later, state fixed effects, and year fixed effects, and weighted by state population. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

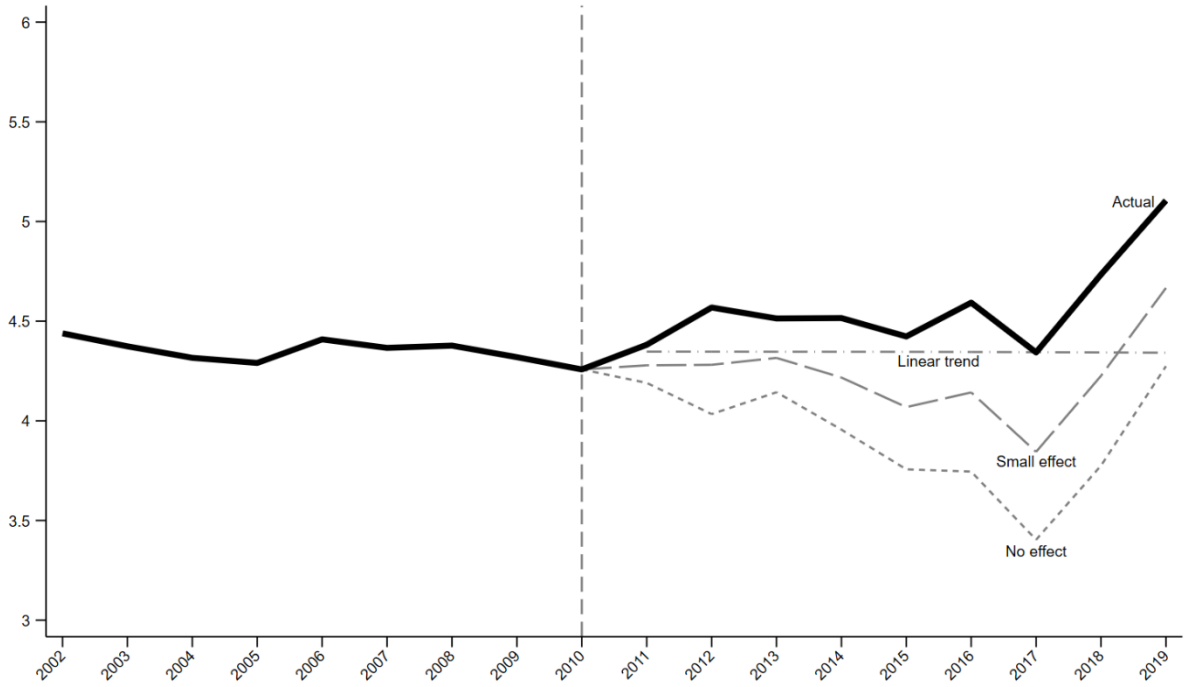
Table 4: Effect of 2010 OxyContin Reformulation on SUT facilities and inpatient beds per 100,000 by Medicaid expansion status

	All	Opioid Treatment Programs	Medication - assisted treatment (non-OTP)	Outpatient only	Inpatient only	Outpatient and inpatient services	Inpatient beds
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OxyContin effect	1.11***	0.07	1.03***	1.01***	0.18	-0.10	8.50*
	(0.40)	(0.08)	(0.29)	(0.30)	(0.14)	(0.11)	(4.66)
(OxyContin effect) x (Medicaid expansion)	1.11*	0.09	0.133	1.01*	0.02	0.08	18.6***
	(0.66)	(0.09)	(0.236)	(0.58)	(0.13)	(0.10)	(5.24)
Medicaid expansion	1.16	0.16	0.11	1.19*	0.05	-0.10	-9.86
	(0.85)	(0.14)	(0.28)	(0.67)	(0.17)	(0.16)	(6.94)
Observations	3219	3219	3219	3219	3219	3219	2821

Notes: Standard errors clustered at state level in parentheses. Estimated using "stacked" difference-in-differences with never treated and not-yet-treat states as controls. The OxyContin reformulation effect is the coefficient from an interaction between the state 2004-2009 OxyContin misuse rate and an indicator for year 2011 or later. All regressions include an interaction between the state 2004-2009 pain reliever misuse rate and an indicator for year 2011 or later, and interaction with the pain reliever misuse variable and Medicaid expansion status, state fixed effects, "stack" fixed effects, and year fixed effects, and weighted by state population. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

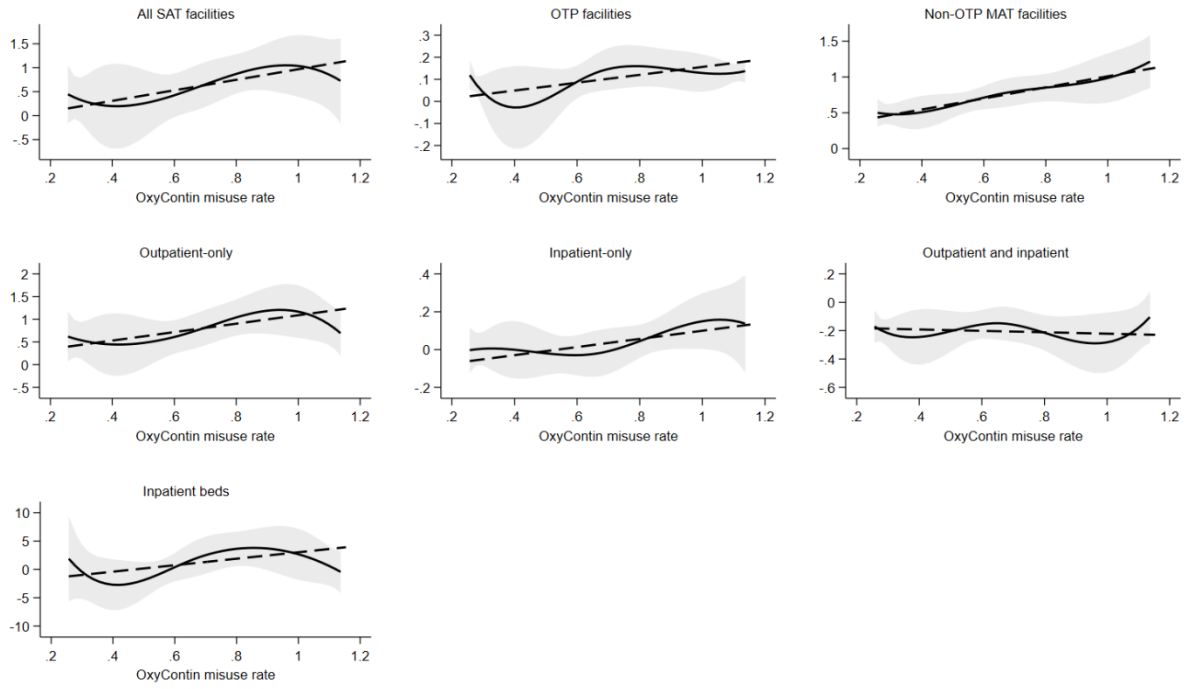
Appendix

Appendix Figure A1: Actual and counterfactual estimates of SUT facilities per 100,000



Notes: Linear trend is estimated from a linear trend of SUT facilities per 100,000 from 2002-2010. "Small effect" is predicted using event study estimates at the lowest OxyContin misuse rate (0.26). "No effect" is predicted using event study estimates where the OxyContin misuse rate is set to zero. Data on SUT facilities from 2002-2019 National Survey of Substance Abuse Treatment Services. Population data from Population data from the U.S. National Cancer Institute's Surveillance, Epidemiology, and End Results Program for 2010. Black line shows actual number of SUT facilities per 100,000.

Appendix Figure A2: Non-parametric estimates and 95 percent confidence intervals and simple linear effect comparisons



Notes: Nonparametric estimates and 95 percent confidence intervals from non-parametric regression of difference in pre and post period means on 2004-2009 OxyContin misuse rate using cubic B-spline and one knot. Dashed black line represents linear fit of OxyContin misuse rate and difference in average outcomes in the pre and post periods.

Table A1: Effect of 2010 OxyContin Reformulation on SUT facilities and inpatient beds per 100,000

	All	Opioid Treatment Programs	Medication-assisted treatment (non-OTP)	Outpatient only	Inpatient only	Outpatient and inpatient services	Inpatient beds
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Only fixed effects							
OxyContin Effect	1.33**	0.11**	0.74***	1.11***	0.23**	0.001	12.6**
	(0.51)	(0.05)	(0.22)	(0.40)	(0.10)	(0.08)	(4.80)
Panel B: Control for other substance use changes after 2010							
OxyContin Effect	1.65***	0.09	1.18***	1.38***	0.27*	0.001	12.6***
	(0.52)	(0.06)	(0.24)	(0.40)	(0.16)	(0.10)	(4.54)
Panel C: Simple regression							
OxyContin Effect	1.09*	0.18*	0.77***	0.93*	0.21*	-0.05	5.54
	(0.57)	(0.09)	(0.23)	(0.49)	(0.12)	(0.14)	(4.16)
Panel D: Cubic B-spline							
OxyContin Effect	0.66	0.06	0.75***	0.50	0.19	-0.03	0.51
	(0.52)	(0.04)	(0.23)	(0.40)	(0.12)	(0.12)	(4.64)
Panel E: OxyCodone MME per capita							
Oxycodone Effect	2.94*	0.40**	2.89***	2.18	0.24	0.52	-0.02
	(1.71)	(0.20)	(1.04)	(1.58)	(0.34)	(0.42)	(0.16)

Notes: Standard errors clustered at state level in parentheses. The OxyContin effect is the coefficient from an interaction between the state 2004-2009 OxyContin misuse rate and an indicator for year 2011 or later. Panel A estimates equation (2) without controlling for changes in pain reliever misuse.

Panel B controls for a level shift in state alcohol, cannabis, and cocaine use rates after 2010. Regressions in Panels A and B include state fixed effects and year fixed effects, and are weighted by state population. Panel C estimates the difference in pre and post period means on the pre-period OxyContin misuse rate. Panel D estimates the difference in pre and post period means on the pre-period OxyContin misuse rate using a cubic B-spline with one knot with 1,000 bootstrap replications. Standard errors in Panel D calculated using the Delta-method. Panel E replaces the OxyContin misuse variable in equation (2) with the 2004-2009 average retail shipments of oxycodone morphine milligram equivalents per capita and includes state fixed effects, year fixed effects, and weighted by population. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A2: Difference between observed and counterfactual estimates of SUT facilities by year

Year	Linear trend	Lowest exposure to reformulation	No Exposure to reformulation
2011	106	317	590
2012	684	887	1651
2013	516	611	1144
2014	522	921	1728
2015	238	1094	2059
2016	765	1391	2617
2017	-2	1541	2903
2018	1209	1570	2961
2019	2359	1356	2568
Average	711	1076	2025

Notes: Counterfactual estimates per 100,000 converted to counts using 2010 US population estimate. For the counterfactual estimates, the linear trend is estimated from a linear trend of SUT facilities per 100,000 from 2002-2010. Lowest exposure is predicted using event study estimates at the lowest OxyContin misuse rate (0.26). No exposure is predicted using event study estimates where the OxyContin misuse rate is set to zero. Data on SUT facilities from 2002-2019 National Survey of Substance Abuse Treatment Services. Population data from Population data from the U.S. National Cancer Institute's Surveillance, Epidemiology, and End Results Program.