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Measuring the Local Supply of Prescription Opioids*

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Abstract

Despite the growth in the literature on the opioid crisis, questions remain on how to best measure the local supply of prescription opioids. We document that measures based on the number of prescriptions largely track hydrocodone, while measures based on morphine-equivalent amounts largely track oxycodone. This choice matters, given the well-documented link between oxycodone and the rise in use of illicit opioids such as heroin, plus the fact that oxycodone and hydrocodone (the two most common prescription opioids) are only weakly correlated. We recommend local measures of the supply of opioids should take into account morphine-equivalent amounts, to avoid understating the health and economic consequences of opioid abuse.

Keywords: opioid crisis; labor force; manufacturing

JEL: J21, I12, I18

*The views expressed in this paper are our own and do not reflect the views of the Federal Reserve System or its staff.

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1 Introduction

The death toll from the opioid epidemic remains staggering and continues to increase over time, with almost 70 thousand deaths from overdoses related to opioids in 2020, adding to around 500 thousand deaths from 2000-2019.¹ Although the opioid crisis began as a *prescription opioid crisis*, deaths involving illicit opioids such as heroin and fentanyl skyrocketed in the 2010s; in 2019 and 2020, deaths involving illicit opioids accounted for over 80 percent of all opioid-related deaths. Monitoring the distribution of prescription opioids and understanding the link between licit and illicit opioids such as heroin and fentanyl remains a pressing issue for policy-makers and researchers. Indeed, a wide research agenda studies the links between the prescription and illicit opioid crises and various health outcomes, the labor market effects of the opioid crisis, and broader economic effects on households, firms, and local governments.

We analyze a central choice in research design in much of this literature: how to measure the local supply of prescription opioids. Measures of the local supply of opioids are often used as a proxy for misuse of prescription opioids, given the inherent difficulties in constructing accurate and comprehensive measures of misuse.² To measure the local availability of prescription opioids, one approach is to measure a prescription rate, defined as the number of opioid prescriptions per capita. An alternative approach is to measure the amount of prescription opioids in morphine-milligram equivalents (mme) per capita. That is, this second approach takes into account not only the extensive margin (the number of prescriptions) but also the intensive margin (the morphine-equivalent amount of opioids per prescription). Both approaches are common in the literature. For example, focusing on studies that examine the labor market effects of the opioid crisis, [Aliprantis et al. \(2019\)](#), [Currie et al. \(2019\)](#), and [Maestas and Sherry \(2020\)](#) use measures based on the number of prescriptions in their baseline, whereas [Cho et al. \(2021\)](#), [Park and Powell \(2021\)](#), [Charles et al. \(2018\)](#), and [Krueger \(2017\)](#) use measures based on prescription opioid morphine-equivalent amounts per capita. It is not obvious how consequential this choice is; all else equal, an increase in the number of prescriptions also implies higher morphine-equivalent amounts.

We show that this measurement choice matters, as it will determine whether the measure of local prescription opioid supply is largely based on oxycodone or hydrocodone. While both oxycodone and hydrocodone products are the most common prescription opioids, they are imperfect substi-

¹See "[Overdose Death Rates](#)" (National Institute on Drug Abuse)

²Researchers with individuals' claims data can derive behavioral measures based on, for example, frequent, large refills from multiple prescribers ([Heins et al. 2021](#), [Wen et al. \(2019\)](#)). However, the claims data do not generally track misuse by persons without a prescription and may track specific groups (e.g. Medicaid population). An alternative is using data from the National Survey of Drug Use and Health (NSDUH), although NSDUH estimates at the state-level are only available for two-year periods. Additionally, NSDUH estimates tend to be noisy, given the well-known tendency of respondents to underreport illicit drug use in surveys, although, in practice, measures of OxyContin misuse from NSDUH are well-correlated with local measures of oxycodone supply ([Alpert et al. 2018](#)).

tutes. Oxycodone tablets are generally stronger and lack other ingredients that most hydrocodone tablets have, such as acetaminophen, that can be toxic in large doses. Indeed, medical studies and surveys generally find that opioid misusers prefer oxycodone (Wightman et al. 2012 and Cicero et al. 2013). We document that measures based on the number of prescriptions (e.g. the prescription rate) will largely track hydrocodone, as hydrocodone is more commonly prescribed, whereas measures based on morphine-equivalent amounts will instead largely track oxycodone, as oxycodone is much more potent. Further, we document that amounts per capita of oxycodone and hydrocodone are only weakly correlated. Hence, measures of the local supply of prescription opioids based on hydrocodone are likely to have distinct information content compared to measures based on oxycodone.

We discuss a few major instances when these distinctions matter. For example, the rise in illicit opioid use such as heroin and fentanyl is directly linked to oxycodone rather than hydrocodone. Additionally, the measured association between the misuse of opioids and labor force participation is more strongly negative for oxycodone and heroin than for hydrocodone. Also, oxycodone amounts per capita are weakly and negatively correlated with the share of employment in goods-producing industries like manufacturing, whereas the correlation is strongly positive for hydrocodone. Hence, measures primarily based on hydrocodone are more likely to both miss some of the most damaging consequences of opioid misuse while also picking up confounding factors related to industry composition. Given these findings, we suggest that researchers interested in constructing local area aggregates of prescription opioids do so using morphine-equivalent amounts rather than the number of prescriptions alone. Of course, some researchers may have specific objectives such as measuring oxycodone or hydrocodone specifically.

We begin by documenting stylized facts regarding oxycodone and hydrocodone. At the peak of the prescription boom in 2010, oxycodone shipments in morphine-equivalent grams and total oxycodone expenditures were about two times larger than for hydrocodone. However, the number of oxycodone tablets was only half that of hydrocodone, since oxycodone tablets are much stronger. Given hydrocodone is more commonly prescribed, we argue measures of local opioid supply that track the number of prescriptions will primarily track hydrocodone rather than oxycodone.

Indeed, we document this is the case using two comprehensive and widely used datasets. We measure the number of prescriptions opioids from the Center of Disease, Control, and Prevention (CDC) and the amount in morphine-equivalent grams of prescription opioids from the Drug Enforcement Administration's Automation of Reports and Consolidated Orders System (ARCOS). To the best of our knowledge, we are the first to compare these two widely used datasets. The CDC estimate of the aggregate number of opioid prescriptions is measured from the IQVIA Xponent database, a large sample of retail pharmacies. These estimates count the number of prescriptions, that is, they are not adjusted for prescription strength (amounts in grams of the active ingredient

per prescription). In contrast, ARCOS estimates are based on administrative data on shipments from drug manufactures and distributors to local buyers, primarily pharmacies. The units of the shipments are in grams of the active ingredient, by opioid prescription type (e.g. oxycodone), which we then convert into morphine-equivalent units using standard conversion factors.³

Using a state-year panel, we estimate that ARCOS hydrocodone per capita shipments (in morphine-equivalent grams) alone explain about 70 percent of the variation in the CDC prescription opioid rate, while ARCOS oxycodone per capita shipments alone explain a more modest 20 percent. We find that shipments to mail-order pharmacies and non-pharmacies do not explain this difference. Further, the ARCOS measures of oxycodone and hydrocodone per capita shipments are largely uncorrelated, perhaps reflecting differences in supplies. Finally, we compare these data sources in 2015, the only year in which CDC estimates of the amount of morphine-equivalent grams of prescription opioids are available.⁴ Across states, the 2015 CDC amounts per capita are much more highly correlated with ARCOS oxycodone shipments per capita than either CDC prescription rates or ARCOS hydrocodone shipments per capita, consistent with our general finding that per capita measures based on morphine-equivalent amounts are more likely to track oxycodone.

Next, we discuss important considerations for researchers using measures of local prescription opioid supply based primarily on either hydrocodone or oxycodone. The information content in these measures is fairly distinct, as they are largely uncorrelated both over time and across places. Measures based on hydrocodone are likely to majorly understate the health and economic effects of opioid misuse, given the well-documented link between oxycodone abuse and use of illicit opioids such as heroin ([Alpert et al. 2018](#), [Evans et al. 2019](#), [Powell and Pacula 2021](#), [Cho et al. 2021](#)). We review some of the evidence linking oxycodone to the rise in illicit opioid use and show this link would be missing, to an econometrician, when using data on either the CDC prescription rate or ARCOS hydrocodone shipments per capita. If anything, hydrocodone shipments per capita seem negatively associated with the rise in overdose deaths related to heroin or fentanyl.

In addition to the health effects, we show that the correlation between labor force participation and opioid misuse varies notably by the type of opioid. We employ data from the National Survey of Drug Use and Health (NSDUH) to estimate individual-level models of labor force participation. The estimates show recent misusers of a broad class of prescription opioids (including oxycodone and hydrocodone) are about 1 percentage point less likely to be in the labor force than non-users. This negative association is largely driven by recent misuse of oxycodone specifically, with persons reporting recent misuse of oxycodone about 5 percentage points less likely to be in the labor force than non-users. The difference is even starker (about 14 percentage points) for recent heroin users.

³See for instance “[Calculating Totally Daily Dose of Opioids for Safer Dosage](#)” (Center for Disease, Control, and Prevention).

⁴[Krueger \(2017\)](#) and [Charles et al. \(2018\)](#) use data from this cross-section.

Substantial differences across opioid types remain when controlling for various individual characteristics, including a dichotomous variable indicating labor force exit due to disability. Although these results are observational rather than causal, the differences in participation rates across opioids are meaningful, suggesting this heterogeneity is likely relevant to studies on both the effects of opioid misuse on economic activity and viceversa.⁵

We also discuss the association between per capita shipments of oxycodone and hydrocodone with employment shares in manufacturing and other goods-producing sectors. We find an only weak (and negative) association for oxycodone shipments, but a strong and positive correlation for hydrocodone shipments (and the CDC prescription rate). The difference in the correlation with the goods-producing share of employment could be explained by geographic differences in the demand or supply of hydrocodone versus oxycodone. Regarding differences in demand, are workers in goods-producing industries more likely to use hydrocodone than oxycodone? Using data from NSDUH, we estimate individual-level models of misuse of hydrocodone, oxycodone, and heroin. But we do not see a strong industry pattern such that workers in goods-producing industries report higher rates of hydrocodone misuse but not misuse of oxycodone or heroin. Rather, industry patterns seem common *across* opioid types. Regarding supply, these differences have likely mattered. Based on analysis of unsealed court documents, [Alpert et al. \(2019\)](#) and [Powell \(2021\)](#) find that early differences across geographies in aggressive marketing tactics by Purdue Pharma, the manufacturer of OxyContin, continue to explain differences in the supply of oxycodone and death rates related to opioid overdoses.

Given the strong and positive correlation between goods-producing employment shares and hydrocodone shipments, labor market studies based on hydrocodone or prescription rates may pick up confounding factors related to industry composition. In particular, the secular decline of the employment to population share in goods-producing industries like manufacturing are well-known ([Howes \(2020\)](#), [Charles et al. \(2018\)](#), e.g.). To illustrate the potential for omitted variable bias, we estimate state-level models of employment to population (EPOP). These models show that initial hydrocodone exposure in 2000 helps explain subsequent relative declines in EPOP, but only when not accounting for differences in industry composition. To be clear, as discussed by [Beheshti \(2019\)](#) and [Aliprantis et al. \(2019\)](#), among others, the possibility of confounding factors related to industry composition is not new. Rather, we make the distinction here that this concern seems specific to hydrocodone and the CDC prescription rate.

In sum, this paper highlights some of the important – and previously less well understood – implications of using different measures of the supply of prescription opioids. Measures based primarily on hydrocodone are more likely to pick up confounding factors related to industry composition

⁵While we do not attempt to estimate causal effects on the LFPR, we note that [Cho et al. \(2021\)](#) and [Park and Powell \(2021\)](#) find that the rise in illicit opioid use has likely weighed on LFPR over the last decade.

while missing important variation related to the rise in heroin and other illicit drug use. Given these results, we suggest that researchers interested in local area aggregates of prescription opioids use prescription amounts (in morphine-equivalent units) rather than the number of prescriptions alone. That said, there are specific instances (e.g., [Beheshti \(2019\)](#) or [Cho et al. \(2021\)](#)) when researchers may want to measure hydrocodone or oxycodone specifically.

Our findings are broadly applicable to the large and growing literature that studies the economic and health effects of the opioid crisis. For example, recent research studies the effects of the opioid crisis on local government finances ([Cornaggia et al. 2021](#); [Li and Zhu 2019](#); [Weeks and Sanford 2019](#)); the labor market ([Charles et al. \(2018\)](#); [Harris et al. \(2020\)](#); [Aliprantis et al. \(2019\)](#); [Currie et al. \(2019\)](#)); corporate finance ([Ouimet et al. 2021](#); [Rietveld and Patel 2020](#)); and consumer credit ([Custódio et al. 2021](#); [Jansen 2021](#)). On the health side, a large literature studies the effects of policy interventions on prescription outcomes: such as the effects of prescription drug monitoring programs ([Buchmueller and Carey 2018](#); [Grecu et al. 2019](#); [Horwitz et al. 2018](#); [Meara et al. 2016](#)); abuse-deterrent reformulations ([Evans et al. 2019](#); [Alpert et al. 2018](#); [Park and Powell 2021](#); [Powell and Pacula 2021](#)); and other supply-side policies such as drug reschedulings and limits on initial prescription length ([Beheshti 2019](#); [Sacks et al. 2019](#)).

2 Data and Descriptive Statistics

We use data from several sources to measure the distribution of prescription opioids. We use the Drug Enforcement Administration’s (DEA) Automation of Reports and Consolidated Orders System (ARCOS) for data on shipments of controlled substances (including opioids used in prescriptions) from distributors and manufacturers to buyers, predominantly pharmacies. We rely on both the published files as well as the 2006 to 2012 microfiles released by the Washington Post and the Charleston Gazette-Mail of West Virginia.⁶ The latter contain much more detail, allowing us, for example, to distinguish whether shipments to a given state went to local pharmacies or other types of establishments, such as hospitals or teaching institutions. For estimates on both the number of people with prescriptions and total spending on prescriptions, we use data from the Medical Expenditure Panel Survey (MEPS), conducted by the Department of Health and Human Services’ Agency for Healthcare Research and Quality (AHRQ).⁷ Additionally, we use data published by the Center for Disease Control and Prevention (CDC) on the number of opioid prescriptions (which

⁶Rich, Steven, María Sánchez Díez, and Kanyakrit Vongkiatkaorn. “How to download and use the DEA pain pills database.” *The Washington Post*. July 18, 2019.

⁷Conducted since 1996, the MEPS is a nationally representative survey containing household demographics and various health conditions and outcomes, including total expenditures on prescriptions (inclusive of both out-of-pocket and insurance payments). See “[Agency for Healthcare Research and Quality: About MEPS](#)” for more information.

combines hydrocodone and oxycodone in the same measure). The source for the CDC data is the IQVIA Xponent database.⁸ We also use the CDC published regional estimates of the amount of opioids prescribed (in morphine-milligram equivalents), but this dataset is only available for the year 2015.⁹

To measure health and economic outcomes that we relate to the distribution of prescription opioids, we use several other sources. To measure overdose deaths related to opioids, we employ the restricted use version of the cause-of-death data from the National Vitality Statistics System managed by the Center for Disease Control and Prevention. We also employ individual-level data from the National Survey of Drug Use and Health (NSDUH) to measure misuse of opioids including heroin as well as demographics and labor force participation. To measure population size when constructing rates, we rely on both counts from the the Current Population Survey (ages 16 to 64) for state-level measures. Finally, we employ data on industry composition from the Quarterly Census of Employment and Wages (QCEW). This allows us to measure the correlation between industry composition (e.g., manufacturing employment shares) and exposure to different prescription opioids.

We begin by documenting stylized facts about the two largest prescription opioids, oxycodone and hydrocodone, using data from ARCOS and MEPS. While oxycodone and hydrocodone are both prescription opioids, they are imperfect substitutes for at least a few reasons. Oxycodone tablets are generally much stronger than hydrocodone tablets. Also, most types of hydrocodone, such as Vicodin, contain acetaminophen, which deters some abuse, as acetaminophen is highly toxic when consumed in high doses. Medical studies and survey responses generally show opioid misusers prefer oxycodone, consistent with oxycodone tablets being stronger and lacking other ingredients (Wightman et al. 2012 and Cicero et al. 2013).

The top left panel of figure 1 shows the ratio of oxycodone to hydrocodone for both ARCOS shipments (in morphine-equivalents) and MEPS expenditures.¹⁰ Oxycodone shipments and expenses increased much more during the second half of the 2000s. In 2010, at the peak of the prescription boom, oxycodone shipments and expenditures were over two times as large as for hydrocodone. In contrast, as shown in the top right of figure 1, the oxycodone to hydrocodone ratio has fluctuated around 0.5 for both the number of pills (from ARCOS microfiles) and the number of prescriptions

⁸Prescriptions are defined as new or refill prescriptions dispensed at retail pharmacies and paid for by commercial insurance, Medicaid, Medicare, cash or other third-party coverage. See “Centers for Disease Control and Prevention: U.S. Opioid Dispensing Rate Maps.”

⁹For more information on this special edition of CDC data, see “Vital Signs: Changes in Opioid Prescribing in the United States, 2006-2015”.

¹⁰The morphine-equivalent conversion factor for oxycodone is 1.5 and 1 for hydrocodone. That is, 1 gram of oxycodone is 1.5 times as strong as 1 gram of hydrocodone. See “Department of Health and Human Services: Opioid Morphine EQ Conversion Factors” for more information. For the ARCOS data, we employ here the 2006-2012 microfiles.

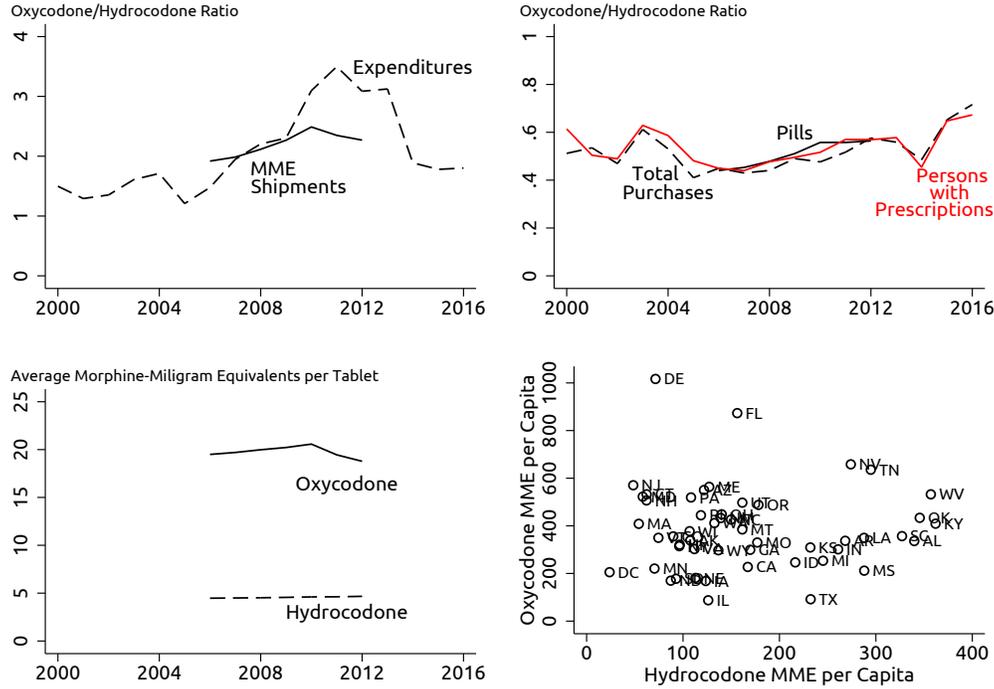
(from MEPS).¹¹

In sum, oxycodone expenditures and morphine-equivalent shipments are generally larger, even though the number of prescriptions and tablets of hydrocodone are typically larger. The bottom left of figure 1 shows that the average oxycodone tablet contained almost 20 milligrams (in morphine-equivalents) compared with almost 5 milligrams for hydrocodone during the 2006 to 2012 period.

The next section discusses the association between per capita oxycodone and hydrocodone shipments and the CDC prescription rate. To preview some of the results, the information content in oxycodone and hydrocodone shipments is quite distinct across both time and cross-section.. The bottom right of figure 1 shows that in the cross-section of states, oxycodone and hydrocodone shipments per capita are weakly correlated.

¹¹To obtain the number of tablets, we merge data on the number of packages shipped from the 2006-2012 ARCOS microfiles with information on the amount of tablets per package from the National Drug Code Dictionary. For ARCOS reporting purposes, each shipment has a unique national drug codes (NDC) that identifies the number of units (i.e., tablets) per package. For more information, see [“ARCOS NDC Dictionary File Record Layout”](#).

Figure 1: Stylized facts regarding oxycodone and hydrocodone



Note: MEPS measurements included for oxycodone, acetaminophen-oxycodone, and acetaminophen-hydrocodone. The bottom right panel plots the state-level 2006-2012 average of oxycodone and hydrocodone mme per capita shipments.

Source: ARCOS Washington Post and Charleston Gazette-Mail of West Virginia for 2006 to 2012 oxycodone and hydrocodone shipments. MEPS for oxycodone and hydrocodone expenditures and number of purchases (new prescriptions and refills) and persons with prescriptions.

2.1 CDC prescription rates and ARCOS shipments of oxycodone and hydrocodone

Given the fact that the number of hydrocodone prescriptions is larger, measures based on the number of prescriptions are likely to largely track hydrocodone. Indeed, we find this is the case comparing ARCOS shipments of oxycodone and hydrocodone and the CDC number of opioid prescriptions. To the best of our knowledge, we are the first to compare these widely used datasets.

First, we compare the cross-section of states. Table 1 provides state-level correlation coefficients between averages from 2006 to 2012 of the CDC opioid prescription rate and ARCOS oxycodone and hydrocodone mme shipments per capita. ¹² Table 1 shows that CDC opioid prescription

¹²We focus on the period 2006-2012 due to data limitations. CDC opioid prescription data are first available in 2006 and the ARCOS microfiles are available from 2006 to 2012. This period covers the height

Table 1: Pairwise correlations between state-level prescription opioid measures and industry composition

	Rx rate	Oxycodone	Hydrocodone	Oxycodone (local pharm)	Hydrocodone (local pharm)	Goods share	Manufacturing share	Mining share	Construction share
Rx rate	1.000								
Oxycodone	0.313	1.000							
Hydrocodone	0.834	0.042	1.000						
Oxycodone (local pharm)	0.319	0.991	0.044	1.000					
Hydrocodone (local pharm)	0.856	-0.031	0.956	-0.025	1.000				
Goods share	0.582	-0.177	0.463	-0.158	0.546	1.000			
Manufacturing share	0.449	-0.166	0.324	-0.142	0.394	0.877	1.000		
Mining share	0.146	-0.128	0.160	-0.137	0.213	0.118	-0.328	1.000	
Construction share	0.227	0.150	0.264	0.139	0.236	0.132	-0.290	0.555	1.000

Note: Averages from 2006 to 2012 of the number of prescriptions and mme shipments of oxycodone and hydrocodone relative to the population aged 16 to 64. Local pharmacies defined as chain and retail pharmacies. Employment shares measured in the year 2000. All U.S. states and the District of Columbia included.

Source: CDC for opioid prescription rates; ARCOS for oxycodone and hydrocodone shipments; QCEW for Service, Manufacturing, Mining, and Construction share in a state; CPS for population aged 16 to 64.

(Rx) rates are positively correlated with both hydrocodone and oxycodone shipments per capita. However, the correlation is much higher with hydrocodone (about 0.8) than with oxycodone (about 0.3). These correlations are similar whether we include only oxycodone or hydrocodone shipments to local chain and retail pharmacies or a broader category of shipments. Lastly, we note that oxycodone and hydrocodone shipments per capita are weakly uncorrelated, as shown both in table 1 as well as in the bottom right panel of figure 1. Later in the paper, we will return to this table when discussing the much higher correlation between employment share in manufacturing (and other goods-producing industries) and both the CDC prescription rate and hydrocodone shipments per capita.

Next, we use a state-year panel to compare CDC opioid prescription rates and ARCOS shipments per capita. We estimate the following equation:

$$Prescription\ rate_{s,t} = \delta_t + \gamma_s + \alpha Oxycodone_{s,t} + \beta Hydrocodone_{s,t} + \epsilon_{s,t} \quad (1)$$

Where the dependent variable is the prescription rate and explanatory variables include oxycodone and hydrocodone shipments per capita within the same year as well as state and year fixed effects in

of the prescription boom.

Table 2: Association between state-year CDC opioid prescription rates and ARCOS oxycodone and hydrocodone mme shipments per capita

	Dep var: CDC/IQVIA Prescription Rate						Dep var: Hydrocodone			
	Model 1 Coef/SE	Model 2 Coef/SE	Model 3 Coef/SE	Model 4 Coef/SE	Model 5 Coef/SE	Model 6 Coef/SE	Model 7 Coef/SE	Model 8 Coef/SE	Model 9 Coef/SE	Model 10 Coef/SE
Hydrocodone	3.144*** (0.23)				2.926*** (0.25)	1.639*** (0.33)	3.091*** (0.21)			
Oxycodone		0.983*** (0.19)			0.669*** (0.12)	0.350*** (0.09)		0.850*** (0.23)	0.107 (0.07)	0.002 (0.02)
Hydrocodone (local pharmacies)			3.376*** (0.30)							
Oxycodone (local pharmacies)				0.650*** (0.20)						
State and year fe	No	No	No	No	No	Yes	No	No	No	Yes
Weighted	No	No	No	No	No	No	Yes	Yes	No	Yes
R-squared	0.71	0.21	0.72	0.12	0.81	0.97	0.61	0.22	0.03	0.90
Observations	765	765	357	357	765	765	765	765	765	765

Note: Hydrocodone and oxycodone shipments in morphine-equivalent grams per population aged 16 to 64. Opioid prescription rates also relative to population aged 16 to 64. Shipments include shipments to chain and retail pharmacies only (columns 3-4) or shipments to all pharmacies, hospitals, and providers (other columns). Data from 2006 to 2012 in columns 3-4, and 2006 to 2020 in all other columns. All U.S. states and the District of Columbia included. Standard errors clustered by state. *** Significant at 1 percent.

Source: CDC for prescription rates; ARCOS for oxycodone and hydrocodone shipments; CPS for population aged 16 to 64.

some specifications.¹³ Oxycodone and hydrocodone shipments are measured in grams (morphine-equivalents) per capita. The main specifications include data from 2006 to 2020, while specifications using the ARCOS microfiles cover the period 2006-2012.

Table 2 reports the estimates. Column 1 includes only contemporaneous hydrocodone shipments per capita as an explanatory variable: Hydrocodone shipments per capita alone explain about 71 percent of the variation in opioid prescription rates. The coefficient estimate indicates that an increase of 1 hydrocodone gram per capita is associated with an increase in a little over 3 prescriptions per capita. Column 2 includes only oxycodone shipments per capita as an explanatory variable; oxycodone shipments explain only 21 percent of the variation in opioid prescription rates and one additional gram of oxycodone is on average associated with less than one prescription, consistent with oxycodone prescriptions being generally stronger.

Our primary interpretation is hydrocodone shipments explain a much higher share of the variation in CDC opioid prescription rates since hydrocodone prescriptions are a higher share of total prescriptions. However, since CDC prescriptions do not include mail-order pharmacies and non-pharmacy providers, we consider whether the difference in model fit is explained by shipments

¹³Models including lags (shipments in previous years) did not yield significantly different conclusions; results available upon request.

outside local (chain and retail) pharmacies. First, we find that the share of shipments to chain and retail pharmacies relative to total shipments (including shipments to hospitals, practitioners, mail-order pharmacies, and teaching institutions) is similarly high around 0.90 for both oxycodone and hydrocodone (available upon request). More directly, we use the ARCOS 2006-2012 microfiles to measure oxycodone and hydrocodone shipments to chain and retail pharmacies only (for short, we call these “local pharmacies”). When considering this sample, the results in models 3-4 show that hydrocodone and oxycodone shipments explain 72 percent and 12 percent of the variation in prescription rates, respectively. Hence, shipments outside chain and retail pharmacies do not explain a significant portion of the difference in model fit.

We estimate additional equations. In model 5, we include both oxycodone and hydrocodone without additional controls, while in model 6 we include year and locality fixed effects. In model 5, both oxycodone and hydrocodone come in significantly and the coefficient estimates are roughly similar to their counterparts in models 1 and 2, partly as oxycodone and hydrocodone shipments are only weakly correlated (discussed shortly). In model 6, the R-squared is much higher and the coefficient estimates are smaller than their counterparts, likely as state and year fixed effects soak up most of the variation in CDC prescription rates. Models 7-8 estimate equations weighted by state-level population. The estimates are similar, though the model fit for the hydrocodone-only model is smaller (about 60 percent). Finally, models 9 and 10 regress hydrocodone shipments on oxycodone shipments per capita. The estimates in model 9 show the coefficient on oxycodone is not significant, with oxycodone shipments alone explaining only about 3 percent of the variation in hydrocodone shipments. Model 10 adds state and year fixed effects, with the coefficient on oxycodone close to zero and not significant.

Although this comparison is based on two specific datasets, the main takeaway is likely broadly applicable: measures based on the number of prescriptions are likely to largely reflect hydrocodone while measures based on prescription amounts will instead largely track oxycodone. We check this is the case with 2015 data, the only year in which CDC estimates of the *amount* in morphine-equivalent grams of prescription opioids are available. Table 3 shows that, across states, 2015 CDC amounts per capita have a higher correlation with oxycodone shipments per capita. Specifically, the correlation between 2015 state-level ARCOS oxycodone and CDC per capita *amounts* is about 0.8. Meanwhile, the correlation coefficient between ARCOS oxycodone shipments and the CDC *prescription rate* is about 0.5 in 2015 and about 0.3 from 2006 to 2012, as was shown in table 1.¹⁴

If oxycodone and hydrocodone shipments per capita were closely correlated, the distinction might not make a large difference. However, they are only weakly correlated, hence analysis based on either prescription amounts (primarily oxycodone) or prescription number (primarily hydrocodone) might

¹⁴The 2015 CDC dataset of opioid amounts were obtained from the data appendix to [Krueger \(2017\)](#) available [here](#).

Table 3: 2015 pairwise correlations between state-level CDC and ARCOS shipments

	MME per capita	Oxycodone	Hydrocodone	Rx rate
MME per capita	1.000			
Oxycodone	0.782	1.000		
Hydrocodone	0.614	0.079	1.000	
Rx rate	0.843	0.473	0.841	1.000

Note: Year is 2015. All U.S. states and the District of Columbia included.

Source: CDC for prescription amounts in morphine-milligram equivalents (mme) per capita and opioid prescription rates (RX rate); ARCOS for oxycodone and hydrocodone shipments.

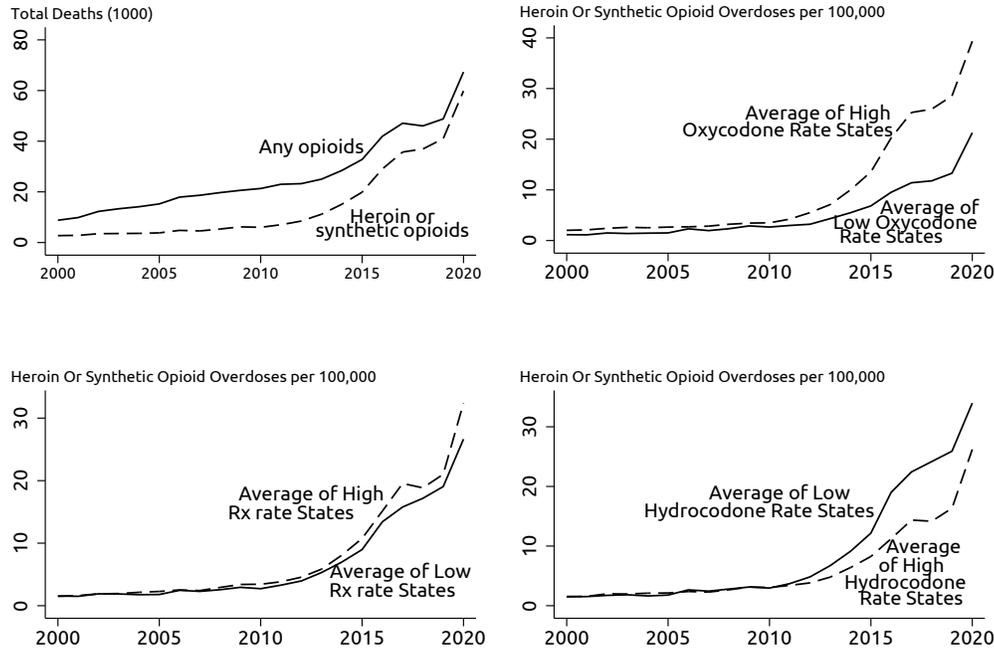
yield substantially different conclusions. In the next sections, we discuss a few major instances when these distinctions are very important: the rise in illicit opioid use such as heroin and fentanyl, the association between opioid misuse and labor force participation, and possible confounding factors related to industry composition.

3 The Oxycodone-Heroin-Fentanyl Epidemic

Understanding the link between prescription and illicit opioid use is important for practitioners, policy-makers and researchers. The top left panel of figure 2 plots the time series of deaths related to opioid overdoses. Though the opioid crisis as a whole began as a *prescription opioid* crisis, deaths involving illicit opioid use, such as heroin, and synthetic opioids, such as fentanyl, skyrocketed in the 2010s. In 2019 and 2020, these deaths accounted for over 80 percent of all overdose deaths involving opioids. How are these crises connected? We briefly review recent research showing a national decline in the supply of oxycodone in 2010 had the unintended consequence of increasing demand and use of illicit opioids. In addition to the negative health effects, survey evidence suggests heroin use is particularly disruptive to economic behavior. Hence, adequately measuring oxycodone is important for researchers proxying for opioid supply or abuse. As detailed in the previous section, opioid supply proxies based on the number of prescriptions will instead largely track hydrocodone.

First, we review the evidence that misuse of oxycodone was an important link between the prescription and illicit opioid crises. Oxycodone has a well-documented history of abuse, with users dissolving pills for non-oral consumption (Hays 2004; Cicero et al. 2005; Cone et al. 2003). As previously discussed, oxycodone tablets tend to be much more potent than hydrocodone tablets and are less likely to include ingredients such as acetaminophen. Indeed, medical studies and surveys show a preference among recreational users towards oxycodone (Wightman et al. 2012). In 2010, following the major increases during the previous decade in oxycodone supply and overdose

Figure 2: Opioid Overdose Deaths



Source: National Vital Statistics System for deaths related to any opioids (T40.0-T40.4, T40.6) and heroin or synthetic opioids (T40.1, T40.3); ARCOS Washington Post and Charleston Gazette-Mail of West Virginia for 2006-2009 oxycodone and hydrocodone shipments; CDC for 2006-2009 prescription rates. Death rates and opioid shipment rates relative to population ages 16 to 64.

deaths, two key developments curbed the supply of oxycodone. First, Purdue Pharma reformulated OxyContin, a popular brand of oxycodone, into an abuse-deterrent formulation that impeded many users from abusing the drug (Severtson et al. 2013b; Severtson et al. 2013a; Cicero and Ellis (2015)). Second, the DEA and local enforcement began to shut down Florida ‘pill mills’, which were clinics with lax standards where physicians prescribed large quantities of oxycodone and other prescription drugs, often to out-of-state buyers (Surrat et al. 2013; Davis and Carr 2017; Temple 2015).

A robust literature has shown that the ensuing reduction in the supply of oxycodone had the unintended consequence of increasing demand and use of heroin in various research settings including: early anecdotes and surveys (Cicero et al. 2012, Cicero and Ellis 2015); structural break techniques (Evans et al. 2019); and event study frameworks (Alpert et al. 2018, Park and Powell 2021, Powell and Pacula 2021, and Cho et al. 2021). Similar to the approaches in this literature, we measure state-level oxycodone exposure as the ratio of oxycodone grams shipped to the state’s chain and retail pharmacies to the state’s population (aged 16-64), both averaged over 2006 to 2009, before the 2010 reduction in oxycodone supply.

The top right panel of figure 2 shows that trends in heroin and synthetic opioids (largely fentanyl) death rates prior to 2010 were similar across states with high and low oxycodone exposure. However, after 2010, death rates related to heroin and synthetic opioids rose nationally, but had a stronger increase in states with previously high oxycodone exposure. As found by [Alpert et al. \(2018\)](#), [Park and Powell \(2021\)](#), [Powell and Pacula \(2021\)](#), and [Cho et al. \(2021\)](#), pre-2010 oxycodone exposure is generally a statistically significant and robust predictor of the increase in heroin and synthetic opioid mortality post-2010.

We provide new results showing this link between oxycodone and the heroin-fentanyl waves of the epidemic would not be visible to an econometrician using data on hydrocodone alone or CDC prescription rates. To see this, we divide states into below and above median exposure to CDC opioid prescriptions per capita (bottom left panel) and to ARCOS hydrocodone shipments per capita (bottom right panel) pre-2010. The bottom left panel of figure 2 shows that heroin or synthetic opioid overdose death rates evolved similarly for both states with above and below median pre-2010 CDC prescription rates. Hence, CDC prescription rates (which are more strongly correlated with hydrocodone shipments per capita) are likely to miss some of the variation related to the increase in illicit opioid use. The bottom right panel in figure 2 shows that while death rates increased strongly for both groups, they, if anything, increased less in states with high pre-2010 exposure to hydrocodone.

4 Differences in labor force participation across opioids

In addition to the health effects, the economic causes and consequences of opioid abuse likely vary by the type of opioid. Indeed, survey data from the National Survey of Drug Use and Health (NSDUH) show that people with recent misuse of oxycodone and heroin are substantially less likely to be in the labor force than persons with recent misuse of other prescription pain relievers including hydrocodone. NSDUH is an annual nationally representative survey of persons aged 12 and over in the civilian noninstitutionalized population.¹⁵ In the survey, respondents are asked about drug use, demographics (including age, industry of employment, education, location, civil status, race and ethnicity) as well as labor force status. Although individual survey responses are anonymized and confidential, illicit drug use in NSDUH is likely undercounted, as individuals tend to underreport drug use especially of heroin and other illegal substances ([Harrell 1997](#); [Colón et al. 2001](#); [Morrall et al. 2000](#)). Moreover, the survey misses some high-risk groups, such as those imprisoned and without a home or shelter.

¹⁵See <https://www.samhsa.gov/data/data-we-collect/nsduh-national-survey-drug-use-and-health> for more information.

Using the NSDUH, we estimate linear probability models of individual i labor force participation based on various demographics and other controls (X_i) as well as recent misuse of different opioids.

$$LF_i = \beta^j \text{Opioid misuse}_i^j + \gamma X_i + \epsilon_i \quad (2)$$

The main explanatory variables of interest are dichotomous variables indicating whether the person has recently (within the past year) misused opioid of type j .¹⁶ We note that these estimates are correlations rather than causal estimates of the effects of misuse of opioids. For example, while use of opioids itself could lead to labor force exits, other confounding factors, such as work injuries, could lead to use of opioids and labor force exits. In these models, we control for various individual characteristics, including in some specifications a variable indicating whether individuals are out of the labor force because of a disability. Across specifications, coefficient estimates for recent misuse of oxycodone and heroin are much larger than for misuse of other prescription opioids, consistent with findings in [Cho et al. \(2021\)](#). These large differences are relevant to research on both the effects of opioid misuse on the labor market and vice versa.

Table 4 reports selected coefficient estimates. The results in column 1 show that persons with recent misuse of prescription pain medications are about 1 percentage point less likely to be in the labor force than those without recent misuse, compared to an average LFPR of around 80 percent. Misuse of prescription pain medication is a broad measure including both oxycodone and hydrocodone products as well as other pain medications. The results in column 2 show that recent misusers of OxyContin, specifically, are about 5 percentage points less likely to be in the labor force than non-misusers.¹⁷ Column 3 shows that when including both measures, the coefficient on OxyContin remains similar while the coefficient on other prescription pain medications is small and not significantly different from zero. While NSDUH does not contain a question for recent misuse of hydrocodone, there is a question for having ever misused hydrocodone. The results in column 4 show that the coefficient estimate for OxyContin is larger than for lifetime use of hydrocodone.

These findings show that the association between LFPR and opioid misuse varies by opioid types. This heterogeneity is clearly relevant to studies on both the effects of misuse on economic activity and viceversa. To be clear, we do not make a causal claim about the effects of misuse on LFPR. This is a complex question, given that unobservables such as worker injuries could be correlated with both drug use and LFPR. That said, we try to address the question: could confounding factors explain why the coefficient on OxyContin is larger than for other prescription drugs? To do so, column 5 includes as a control an indicator for persons who are out of the labor force due to a

¹⁶Opioids misuse in the NSDUH corresponds to opioid use in a way not directed by a doctor, including: use without a prescription; with greater amounts, frequency, or duration than prescribed; use in any other way not directed by a doctor.

¹⁷NSDUH does not contain a specific question about recent misuse of general oxycodone products.

Table 4: Probability of being in the labor force for people ages 24 to 49, 2004-2014

LF=100 or 0							
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
	Coef./SE	Coef./SE	Coef./SE	Coef./SE	Coef./SE	Coef./SE	Coef./SE
Prescriptions past12mo	-1.01** (0.51)		-0.47 (0.54)		-0.40 (0.49)		
OxyContin past12mo		-5.34*** (1.45)	-4.90*** (1.54)	-4.60*** (1.49)	-2.86** (1.30)		
Hydrocodone ever				-1.12** (0.52)			
Heroin past12mo						-14.29*** (2.43)	-8.20*** (1.95)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Disability	No	No	No	No	Yes	No	Yes
R-squared	0.06	0.06	0.06	0.06	0.22	0.06	0.22
Observations	202213	202213	202213	202213	202213	202213	202213

Note: All columns include as explanatory variables education, race and ethnicity, sex, age, marriage status, year, and metro area location fixed effects. Columns 5 and 7 include a dichotomous variable for persons not in the labor force due to disability. ** Significant at 5 percent. *** Significant at 1 percent.

Source: NSDUH and authors' calculations.

disability. We think this control accounts for confounding factors related to injuries, at the risk of overcontrolling, given that opioid use disorder itself could lead to disability (Park and Powell (2021)). The model fit in column 5 is much higher, as expected, since we are controlling here for persons out of the labor force due to a disability. Still, the coefficient on OxyContin remains significantly larger than for prescription pain medications.

We also examine the association between recent heroin use and the LFPR. Column 6 shows that recent heroin users are about 14 percentage points less likely to be in the labor force than non-users, a difference similar to that between persons without a high school degree and those with a college degree in NSDUH (not shown). Column 7 includes as a control an indicator for disability status. Although smaller, the coefficient on recent heroin use remains large and significant. Heroin use could both be a consequence of disability as well as a cause. For example, heroin use could lead to injuries or illnesses that the Social Security Administration considers basis for disability insurance.¹⁸

Lastly, we briefly discuss recent findings from quasi-experiments showing that the post-2010 increase in heroin use has likely weighed on LFPR. Cho et al. (2021) proxy for the recent increase in heroin use based on the national decline in oxycodone supply in 2010 interacted with pre-2010 variation in

¹⁸See “Disability Insurance - Policy Interpretation Ruling” (Social Security Administration; March 22, 2013)

oxycodone supply across states. As mentioned in section 3, the national decline in oxycodone had the unintended consequence of increasing demand for heroin (Evans et al. 2019, Alpert et al. 2018, Powell and Pacula 2021). Cho et al. (2021) find meaningful negative effects on LFPR, particularly for white, young, and less educated groups, consistent with the profile of oxycodone misusers. Park and Powell (2021) report similar findings, using a similar event study framework with different data on labor market outcomes and oxycodone exposure. These effects may be additional to those from prescription opioid use only. Other studies, focusing primarily on the prescription opioid crisis, such as Harris et al. (2020), Aliprantis et al. (2019), Powell (2021) and Maestas and Sherry (2020) have also found significant negative effects on LFPR from opioid use. In contrast, Currie et al. (2019) find small effects overall, and small positive effects for women.

5 Correlation between goods-producing employment shares with hydrocodone and oxycodone

Table 1 shows the cross-sectional correlation between prescription opioid measures and employment shares (relative to total private employment) in different industries: manufacturing, mining, construction, and goods-producing industries (defined as the share of employment in these industries). These industry shares are measured in the year 2000 while the measures of prescription opioids are measured from 2006 to 2012 due to the availability of the ARCOS microfiles.¹⁹ Oxycodone shipments per capita are, in general, only weakly correlated with the industry shares. For example, oxycodone shipments are weakly negatively correlated with the manufacturing share of employment (about -0.2) and weakly negatively correlated (about -0.2) with the goods employment share. In contrast, correlations with opioid prescription rates and hydrocodone shipments are stronger in absolute terms and flip in sign. For example, opioid prescription rates and hydrocodone shipments are more strongly and *positively* correlated with each of the manufacturing, mining, and construction employment shares, and with the overall employment share in goods-producing industries (with correlations of about 0.6 and 0.5, respectively).

What explains the differences in the correlation between exposure to different prescription opioids and goods-producing industries? These differences could be explained by geographic differences in the supply of hydrocodone compared to oxycodone or variation in demand. Variation in supply is likely to matter. Analyzing unsealed court documents from civil cases against Purdue Pharma, the manufacturer of OxyContin, Alpert et al. (2019) finds that the company viewed triplicate

¹⁹Correlations for other periods are available upon request. We note that both the industry shares of employment and the prescription opioid measures are highly persistent over time. For example, the correlation coefficient across states between 2000 and 2016 hydrocodone shipments per capita is about 0.9. The correlation is similar between the 2000 and 2016 goods-producing employment shares.

prescription laws, an early form of prescription drug monitoring programs, as a major barrier to the prescription of OxyContin and directed its aggressive marketing tactics towards states without these laws in place.²⁰ Alpert et al. (2019) and Powell (2021) find that these early differences in the supply of oxycodone have had persistent implications. Indeed, oxycodone shipments and deaths rates related to opioid overdoses are still substantially lower in states with a triplicate prescription program in 1996, the year of the introduction of OxyContin into the market, than in states without a similar program.

In addition, differences in industry composition across states may also matter to the extent that workers in goods-producing industries use hydrocodone relatively more than in other industries. For example, it could be the case that workers in goods-producing industries are more likely to be prescribed hydrocodone for work related injuries. To explore this possibility, we use data from NSDUH to verify whether employees in goods-producing industries are much more likely to misuse hydrocodone than oxycodone, but do not find much evidence this is the case. Table 5 reports estimates from linear probability models of lifetime misuse of opioids for different opioid products (hydrocodone, oxycodone, and heroin) based on worker industry fixed effects alone (columns 1-3). We also show estimates including other controls (columns 4-6), to at least partially isolate industry effects from variation explained by age, education, or other demographics. The industry effects alone do not explain much of the overall variation in lifetime misuse across opioid products, with the R-squared close to zero across the models without other controls (columns 1-3). That said, there are some statistically significant differences across industries in opioid use. For example, workers in leisure and hospitality and construction tend to have relatively higher misuse than in education and health (the omitted group). These industry differences persist even when controlling for other observables, though they are a bit smaller. In the other direction, workers in public administration tend to report lower misuse than in education and health, with the differences more pronounced when controlling for other demographics. By and large, however, these industry differences seem *common across types of opioids*. For example, workers in construction and leisure and hospitality report higher misuse for hydrocodone, oxycodone, and heroin. Thus, differences in misuse across opioids do not seem so pronounced by worker industry. While we think better understanding heterogeneity in the geography of opioid use by types of opioids is an interesting question, for the rest of the paper, we take the associations reported in table 1 as a given.

²⁰The 5 states with triplicate prescription programs in 1996 were California, Idaho, Illinois, New York, and Texas.

Table 5: Probability of having ever misused opioids for persons ages 24+, 2004 - 2014

Misuse=100 or 0						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Coef/SE	Coef/SE	Coef/SE	Coef/SE	Coef/SE	Coef/SE
Construction	2.410*** (0.26)	2.180*** (0.20)	2.747*** (0.25)	1.049*** (0.27)	0.957*** (0.20)	1.238*** (0.26)
Manufacturing	0.495** (0.20)	0.635*** (0.13)	0.568*** (0.15)	-0.121 (0.20)	-0.001 (0.13)	-0.393** (0.16)
Mining	-0.007 (0.37)	0.230 (0.25)	0.015 (0.24)	-0.354 (0.37)	-0.295 (0.25)	-0.768*** (0.25)
Trade/Transportation	0.755*** (0.17)	0.849*** (0.12)	0.740*** (0.14)	0.023 (0.18)	0.141 (0.12)	-0.146 (0.15)
Information	1.713*** (0.45)	1.203*** (0.33)	0.669** (0.31)	0.939** (0.45)	0.574* (0.32)	0.004 (0.31)
Fin. Activities	0.682*** (0.25)	0.574*** (0.16)	0.093 (0.16)	0.240 (0.25)	0.196 (0.16)	-0.253 (0.17)
Prof/Business Services	1.227*** (0.23)	0.838*** (0.15)	0.597*** (0.15)	0.627*** (0.23)	0.298** (0.14)	0.049 (0.15)
Leisure/Hospitality	3.255*** (0.29)	2.677*** (0.21)	1.877*** (0.22)	1.844*** (0.28)	1.530*** (0.21)	0.979*** (0.22)
Other Services	0.730*** (0.27)	0.702*** (0.19)	0.661*** (0.22)	0.359 (0.27)	0.255 (0.19)	0.004 (0.22)
Public Admin	-0.533** (0.25)	-0.154 (0.16)	-0.237 (0.15)	-0.681*** (0.25)	-0.371** (0.16)	-0.831*** (0.16)
Not in Labor Force	-0.780*** (0.13)	0.102 (0.08)	0.795*** (0.11)	0.590*** (0.14)	0.731*** (0.09)	1.161*** (0.13)
_cons	2.926*** (0.11)	1.151*** (0.06)	0.968*** (0.09)	3.646*** (0.24)	2.722*** (0.18)	2.556*** (0.22)
Other controls	No	No	No	Yes	Yes	Yes
R-squared	0.00	0.00	0.00	0.04	0.03	0.02
Observations	254793	254793	254793	254793	254793	254793

Note: The omitted industry is education and health. Columns 4-6 include as explanatory variables age, education, race and ethnicity, sex, marriage status, year, and metro location fixed effects.

Source: NSDUH.

6 Potential for omitted variable bias in labor market studies

Given the strong positive state-level correlation between goods-producing employment shares and both CDC prescription rates and hydrocodone per capita shipments, studies on the effects of prescription opioid use on labor market outcomes may pick up confounding factors related to

industry composition. For instance, studies that do not adequately account for this correlation may reach wrong conclusions about the effect of prescription opioid use on labor market outcomes. Nationally, the share of employment in goods-producing industries has declined over time for various reasons, including automation and globalization. Indeed, many studies have shown (e.g. [Autor et al. \(2013\)](#), [Charles et al. \(2018\)](#), [Charles et al. \(2016\)](#), [Pierce and Schott \(2016\)](#)) that geographies with more initial exposure to these secular forces have tended to experience relative declines in employment-to-population ratios and labor force participation rates.

We illustrate this point employing an event study framework similar to research designs commonly used in the literature, including [Beheshti \(2019\)](#), [Alpert et al. \(2018\)](#), [Park and Powell \(2021\)](#), and [Cho et al. \(2021\)](#).²¹ We estimate state-level models of the employment-to-population ratio for the prime-age population (persons ages 25 to 54) using data from the Current Population Survey.

$$\begin{aligned}
 EPOP_{s,t} = & \beta_1[1\{2001 \leq t \leq 2010\} \times Hydro_s^{2000}] + \beta_2[1\{2011 \leq t \leq 2019\} \times Hydro_s^{2000}] + \\
 & \alpha_1[1\{2001 \leq t \leq 2010\} \times Oxy_s^{2000}] + \alpha_2[1\{2011 \leq t \leq 2019\} \times Oxy_s^{2000}] + \\
 & \omega_1[1\{2001 \leq t \leq 2010\} \times Goods_s^{2000}] + \omega_2[1\{2011 \leq t \leq 2019\} \times Goods_s^{2000}] + \alpha_s + \gamma_t + \epsilon_{s,t} \quad (3)
 \end{aligned}$$

In addition to state and year fixed effects, we include the interactions between hydrocodone and oxycodone rates (mme shipments per capita) in 2000 and indicator variables for three periods: 1999-2000 as the omitted period; 2001-2010; and 2011-2019. Hydrocodone and oxycodone rates in 2000 are not only highly correlated with both the levels in subsequent years, but also with the increase during the 2000s expansion in prescription opioids.²² We also include in some specifications the interaction of the 2000 goods employment share with the same time periods. We do so, following an approach similar to that in [Charles et al. \(2018\)](#), to flexibly account for trends in the EPOP explained by pre-existing variation in the share of employment in goods-producing industries. The 2000 hydrocodone and oxycodone rates and goods employment shares are normalized to have mean zero and standard deviation of one. All models include state and year fixed effects. Standard errors are clustered by state and results are shown for population-weighted specifications (results are similar without population weights).

²¹We also estimated ordinary least squares models of the EPOP and LFPR in a state-year panel as a function of previous year prescription rates, e.g. $EPOP_{s,t} = \beta RXrate_{s,t-1} + \alpha X_{s,t} + \epsilon_{s,t}$. [Harris et al. \(2020\)](#), [Aliprantis et al. \(2019\)](#), [Currie et al. \(2019\)](#), and [Maestas and Sherry \(2020\)](#) use related approaches though with varying data settings. We find OLS estimates of β to be small and generally negative though positive in some specifications depending on controls. While these estimates generally seem consistent with the mixed findings reported in this literature, direct comparisons are difficult given papers vary in empirical strategy, including time frame, data, and level of aggregation.

²²The correlation coefficient is about 0.8 between the 2000 hydrocodone rate and the increase from 2000 to 2010. For oxycodone, the correlation coefficient between the initial 2000 rate and the change from 2000 to 2010 is about 0.5.

Table 6 shows estimates for the coefficients of interest, which show the relative change in EPOP during the 2000s and 2010s since the pre-period as explained by variation in the goods employment shares and oxycodone and hydrocodone rates in 2000.²³ We present results with and without the interaction of the initial goods share of employment and time periods to see how this inclusion affects the oxycodone and hydrocodone coefficient estimates. The first model shows that areas with higher initial goods employment shares experienced statistically significant relative declines in EPOP over the next two decades. The second model shows that areas with larger initial hydrocodone exposure also seem to have experienced subsequently larger declines in EPOP. However, the third model shows that when accounting for initial variation in the goods share of employment, the coefficients on the interactions of hydrocodone rates with the time period effects are smaller. The coefficient is now very small and close to zero during the 2000s decade when the use of prescription opioids dramatically increased. The coefficient during the 2010s decade is only borderline significant (at the 10 percent level) and about 40 percent lower than in model 2 (without accounting for trends explained by the goods employment share). The fourth model shows coefficient estimates are similar for the EPOP of prime-aged men, who have experienced sharper declines in employment in the past decades.

Estimates in the fifth model show that initial variation in oxycodone exposure is not, at first glance, significantly associated with changes in EPOP. When including the goods share interactions (model 6), the coefficients are a little larger and borderline significant during the 2010s. For men (model 7), the coefficient estimates are again a little larger and more strongly significant in the 2010s. Unlike with hydrocodone, accounting for initial variation in the goods employment share does not lower coefficient estimates closer to zero, rather, if anything, tends to make them larger. While here we report associations rather than causal estimates, we note that these estimates are consistent with those in [Cho et al. \(2021\)](#) and [Park and Powell \(2021\)](#), who argue the increase in illicit opioid use in the last decade – resulting from the decline in oxycodone supplies in 2010 – has meaningfully weighed on EPOP and the LFPR.

To be clear, we do not make a claim about the causal effect of hydrocodone (or oxycodone use) on EPOP or to critique specific findings in the literature. Rather, we illustrate in a simple example the point that studies based on hydrocodone (and hence prescription rates) could be biased if they fail to account for industry composition. [Beheshti \(2019\)](#), [Aliprantis et al. \(2019\)](#), [Maestas and Sherry \(2020\)](#), [Currie et al. \(2019\)](#), and [Charles et al. \(2018\)](#) mention this and related concerns and try to address them in their own context. These papers vary in a number of ways, including data, identification strategy, time frame, and level of aggregation, hence direct comparisons are not straightforward. Here, our relative contribution is to provide a straightforward example of the potential for omitted variable bias. Moreover, we document this concern is specific to hydrocodone,

²³Estimates for the LFPR are qualitatively similar and are available upon request.

given that oxycodone shipments per capita are weakly (and negatively rather than positively) correlated with employment shares in goods-producing industries.

Table 6: Trends in EPOP by initial variation in oxycodone and hydrocodone exposure and goods-producing employment shares, ages 25-54

	Dependent variables:						
	Model 1 Coef/SE	Model 2 Coef/SE	Model 3 Coef/SE	Model 4 Coef/SE	Model 5 Coef/SE	Model 6 Coef/SE	Model 7 Coef/SE
2001 - 2010 \times Goods share (2000)	-0.762*** (0.18)		-0.766*** (0.21)	-0.853*** (0.28)		-0.769*** (0.17)	-0.876*** (0.22)
2011 - 2019 \times Goods share (2000)	-0.694*** (0.25)		-0.532** (0.26)	-0.370 (0.28)		-0.726*** (0.20)	-0.588*** (0.21)
2001 - 2010 \times Hydrocodone rate (2000)		-0.310* (0.18)	0.008 (0.17)	-0.026 (0.18)			
2011 - 2019 \times Hydrocodone rate (2000)		-0.614*** (0.21)	-0.393* (0.23)	-0.422 (0.30)			
2001 - 2010 \times Oxycodone rate (2000)					-0.021 (0.18)	-0.067 (0.17)	-0.123 (0.14)
2011 - 2019 \times Oxycodone rate (2000)					-0.275 (0.17)	-0.319* (0.17)	-0.430** (0.17)
State and year fe	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Weighted	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.83	0.83	0.84	0.83	0.83	0.83	0.83
Observations	1071	1071	1071	1071	1071	1071	1071

Note: All models include data from 1999 through 2019. The goods share and oxycodone and hydrocodone rates in 2000 are normalized to have mean zero and standard deviation of one. Oxycodone and hydrocodone rates defined as mme shipments per population aged 25-54.

Source: CDC for prescription rates; ARCOS for oxycodone and hydrocodone shipments; CPS for population aged 25 to 54 and employment and labor force participation rates; QCEW for goods share.

7 Conclusion

The wide-ranging consequences of the opioid crisis remain staggering and deaths related to opioids continue to increase. In 2020, deaths related to opioids reached new heights, with over 80 percent of deaths involving illicit opioids such as heroin and fentanyl. We contribute to the growing literature on the causes and consequences of the opioid crisis by discussing the merits of alternative measures of the local supply of prescription opioids. We review and present new evidence showing the importance of adequately measuring oxycodone, the largest of the prescription opioids (in morphine-equivalent amounts), and a key link between the prescription opioid crisis and the subsequent heroin and fentanyl crises. We also find that misusers of oxycodone and heroin are less likely to be in the labor force than misusers of other pain killers. These correlations should be informative to studies on

both the effects of opioid misuse on the labor market and vice versa. We also show that studies based on the number of prescriptions are more likely to reflect hydrocodone and hence could understate the negative health and economic consequences of opioid misuse related to oxycodone, while also more likely to pick up confounding factors related to industry composition. Of course, researchers may have different objectives and may intend to measure oxycodone or hydrocodone specifically. That said, for researchers interested in constructing local area aggregates of prescription opioids, we suggest they do so using morphine-equivalent amounts rather than the number of prescriptions.

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