

The War on Drugs: Estimating the Effect of Prescription Drug Supply-Side Interventions*

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Abstract

Prescription drug abuse is America's fastest-growing drug problem, with overdose deaths from opioid pain relievers increasing by 313% from 1999 to 2010. This paper estimates the effect of supply-side interventions on prescription drug availability, abuse, public health, and crime. The study is based in Florida, the epicenter of the prescription drug abuse epidemic in the late-2000s, where physicians prescribing and dispensing oxycodone from pain clinics were the main source of drug diversion. In mid-2010, government officials initiated a sweeping crackdown on Florida's pain clinic suppliers, reducing the number of pain clinic licenses by 59%. Using novel online and administrative data and exploiting the timing and geographic location of the crackdown, I find that enforced regulation of pharmaceuticals' legal supply chain can reduce prescription drug abuse substantially and sustainably. Between 2008-12, oxycodone street prices increased by 238% and average supply decreased by 59%. In turn, indicators of oxycodone consumption decreased significantly. There is no evidence of an oxycodone price, supply, or consumption recovery. There is substitution to heroin, but this offsetting effect is small relative to substantial public health gains from decreases in oxycodone deaths and hospitalizations. In addition, there is weak evidence of a decrease in drug arrests and index crimes.

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1 Introduction

Prescription drug abuse is America's fastest growing drug problem. In 2013, an estimated 6.5 million Americans aged 12 or older reported being non-medical users of prescription drugs in the past month, more than any other illicit drug except for marijuana (NSDUH, 2014). Opioids, used medically to relieve pain, are the most commonly abused prescription drugs. Between 1999 and 2010, opioid pain reliever sales increased fourfold (CDC, 2011). At the same time, opioid pain reliever overdose deaths increased by 313%, from 4,030 to 16,651, exceeding those involving heroin and cocaine combined (CDC, 2015). The rates of neonatal abstinence syndrome, substance abuse treatment admissions, and emergency department visits involving the non-medical use of opioid pain relievers have likewise all increased substantially (Patrick et al., 2012; CDC, 2011; DAWN, 2013).

Reducing prescription drug abuse and its associated costs is an important goal of the federal government, which in 2011 released the Prescription Drug Abuse Prevention Plan.¹ The government controls drug abuse with policy interventions that target either the demand or the supply of drugs.² The question of supply-side intervention effectiveness is especially relevant as this approach receives the bulk of the federal government's drug control spending, yet there is debate regarding its value at the margin. Multiple studies fail to find substantial and sustained effects of increases in

¹This plan includes action in the areas of education, monitoring, medication disposal, and enforcement, and expands upon the National Drug Control Strategy. The NDCS, the federal drug policy plan, includes action in five main areas: treatment, prevention, domestic law enforcement, interdiction and international support. In 2009, the federal drug control spending in these areas amounted to \$15,278.4 million (ONDCP, 2011).

²Prevention and treatment are demand-sided, and seek to deter the consumption of new and existing users. Source country, interdiction, and domestic enforcement are supply-sided, and seek to increase the cost of supplying drugs, therefore raising retail prices and reducing consumption.

enforcement in the market for illegally produced drugs.³

Previous studies, however, may not generalize to controlled prescription drugs. While prescription and illegal drugs' pharmacological effects can resemble each other, prescription drugs have accepted use in medical treatment and thus, can be legally produced and dispensed by registered suppliers. In contrast to illegally produced drugs, supply-side interventions of legally produced drugs can include enforcement through administrative action and other regulatory solutions. Survey data suggests that most diverted prescription drugs are produced by legal suppliers as doctors are patients' original source.⁴ In 2013, 23% of past year non-medical users report obtaining opioid pain relievers from doctors, and 46% report obtaining them for free from a friend or relative who obtained them from doctors (NSDUH, 2014).⁵ Knowingly or unknowingly, healthcare providers play an important role in the diversion of prescription drugs and thus, targeting pharmaceuticals' legal supply chain might yield different results.

This paper estimates the effect of suspending or revoking diverting healthcare providers' license to prescribe or dispense controlled prescription drugs on drug availability, abuse, public health, and crime. This is the first systematic study of supply-

³ See Pollack & Reuter (2014) for a discussion of this literature. DiNardo, 1993; Weatherburn & Lind, 1997; Yuan & Caulkins, 1998; Freeborn, 2009; Miron, 2003; Kuziemko & Levitt, 2004; Dobkin & Nicosia, 2009; Crane, Rivolo & Comfort, 1997; Dobkin, Nicosia & Weinberg, 2014. Results from these studies have been mixed, with most finding no effects, or at best, modest or temporary effects. A notable exception is the Australian heroin drought in 2001, the most severe and long-lasting heroin shortage in the world. However, there is debate regarding whether this draught can be attributed to improved domestic drug enforcement (Wodak, 2008). Note that empirical evidence has found that prohibition raises prices above those likely to pertain under legalization.

⁴ Prescription drugs are diverted from their legitimate sources when they are sold and consumed outside their intended medical purpose.

⁵ The source breakdown is: drug dealers/ stranger (4.3%); internet (.1%); other (4.4%); doctors (23.8%); bought/ took from friend or relative (14.6%); and free from friend or relative (53%). Those in the latter category report their friend or relative obtained the drugs from doctors 87% of the times (NSDUH, 2014).

side intervention effectiveness in the context of controlled prescription drugs.⁶ The study is based in Florida, the epicenter of the prescription drug abuse epidemic during the late 2000s (see Figure ??). Doctors dispensing and prescribing oxycodone and other pharmaceuticals from pain clinics or "pill mills" were a main source of drug diversion.⁷ Pill mills were characterized by nearly exclusive associations with specific pharmacies, cash-based payment methods, and casual examinations (DEA, 2013). In mid-2010, law enforcement and legislative officials initiated a sweeping crackdown on Florida's pill mill suppliers. There were two key aspects to this intervention: (1) Physicians could no longer dispense certain prescription drugs;⁸ and (2) Diverting healthcare providers and facilities had their state medical license/ Drug Enforcement Administration's Certificate of Registration suspended, revoked, or denied, and could no longer handle prescription drugs.

To estimate the effect of prescription drug supply-side interventions on drug abuse and its associated costs, I examine a wide range of outcomes. These include drug street prices, quantities supplied, number of suppliers, deaths, hospitalizations, substance abuse treatment admissions, crime, drug arrests, and full-time police. Data on outcomes are collected from novel online and administrative sources. In this way, I overcome the well known data constraint of quantifying supply and number of suppliers in underground markets faced by illegal drug studies.⁹ The identification

⁶To the best of my knowledge there is a growing literature regarding the effectiveness of methods to address prescription drug abuse, most of which are descriptive or focus on prescription drug monitoring programs. Dobkin, Nicosia & Weinberg (2014) study supply-side interventions in a somewhat related but their focus is on the regulation of over-the-counter drugs which are much less regulated. I focus on the enforcement and regulation of controlled prescription drug suppliers.

⁷In 2009, Florida pharmacies and doctors dispensed nearly 3 and 265 times more oxycodone grams per capita than the average state (ARCOS).

⁸Note that prescribing and dispensing are different concepts. The former orders the use of a medication, while the latter delivers such medication. Note that under these changes, physicians could still prescribe or administer drugs as long as their DEA registration/ state medical license was active.

⁹This paper relies on prescription drug quantity and supplier data, which identifies supply and

strategy is to exploit variation in the timing and geographic location of this large-scale crackdown. I classify estimates for drug outcomes into groups based on active ingredients. Groups include oxycodone, oxycodone's prescription drug complements, oxycodone's prescription and illegal drug substitutes, other illegal drugs, prescription drug stimulants, and prescription drugs used in treatment for opioid addiction.¹⁰

The pill mill crackdown resulted in the closure of many of Florida's pain clinics. From 988 pain clinic active licenses in June 2010, only 407 were still active by the end of 2012, a 59% decline. During this period, oxycodone street prices increased by 238% and average oxycodone supply decreased by 59%, the largest state-level shock to oxycodone supply in over a decade.¹¹ There is no evidence of substantial supply spillovers across states, suppliers, or other opioid pain relievers. Supply reductions were accompanied by significant declines in indicators of non-medical prescription drug consumption. Specifically, opioid pain reliever deaths and hospitalizations decreased, while substance abuse treatment admissions increased. Similar trends are observed for benzodiazepines, opioid pain reliever's complements. There is no evidence of an oxycodone price, supply, or consumption recovery, at least up to three-and-a-half years post-crackdown,¹² which contrasts with results from most illegal drug studies where supply-side interventions have, at best, a short-run effect.^{??}

Some substitution to heroin is found, which is consistent with a recent nationwide spike in heroin overdose deaths anecdotally attributed to initial opioid pain reliever abuse (CDC, 2015). Although heroin deaths and hospitalizations display high post-suppliers by state, healthcare provider type, and active ingredient, and allows tracking supply recovery and spillovers.

¹⁰See appendix for drugs in these groups.

¹¹Note that supply data is available up to 2013, but for consistency across datasets regression analysis is restricted up to 2012.

¹²Florida's Medical Examiners Commission Report shows that in 2014 oxycodone deaths continued to decline, and so, at least for this measure of consumption, the effect persists up to four and a half years post-crackdown.

crackdown growth, the absolute magnitude of this offsetting effect is small relative to substantial public health gains from decreases in oxycodone deaths and hospitalizations. Other illegal drugs appear to be unaffected. This shift in the market for legal and illegal drugs did not result in a rise in criminal activity. If anything, there is weak evidence of a slight decrease in drug arrests, property crimes, and violent crimes. More robust evidence is found for supplier reported drug theft by armed robbery and night break-in, which declined by 57% and 25%, respectively. These findings contrast with studies documenting that crackdowns increase violence (Dell, 2014).

The success of the intervention is likely due to a number of supply and demand side factors. From the supply-side, high entry costs in the market for prescription drugs arising from technological barriers and stringent federal regulation might facilitate production to be contained among legal suppliers. This could explain why legal rather than illegal suppliers are the original source of most diverted prescription drugs.^{??} In this setting, incapacitating suppliers could be more effective because legal suppliers are observable, and if diverting at a large scale, might be easier to identify and remove from the market. Moreover, deterrence effects could be large considering that legal suppliers operate in healthcare markets and it might be difficult for doctors to openly price discriminate against non-medical users or increase legal prices in response to a higher probability of apprehension.¹³ From the demand side, the general belief that prescription drugs are "safer" than illegal drugs (Arria et al., 2008) might have deterred some non-medical users from switching to heroin and instead opt for substance abuse treatment.

While new opportunities for prescription drug diversion might eventually become

¹³Legal prices might be difficult to increase if these are determined by the government, insurers and pharmaceutical companies.

available and continued increase in heroin consumption might eventually reach oxycodone levels, findings from this study suggest that at least in the medium-run, supply-side interventions can be an effective policy tool in the war against prescription drug abuse, especially in the face of an epidemic.

2 Background

2.1 Controlled Prescription Drug Abuse

Prescription drugs are regulated under the 1970 Controlled Substances Act, and the DEA serves as the primary federal agency responsible for its enforcement (DEA, 2006). The Act requires that any person who manufactures, distributes, dispenses, imports, or exports any controlled substance must register with the DEA and keep records of inventories and transactions (Yen, 2012).¹⁴ Substances are classified into five schedules based on abuse potential, likelihood of dependence when abused, and whether they have accepted use in medical treatment (Office of Diversion Control).¹⁵ While schedule I substances have no accepted use in medical treatment, schedules II-V include substances with recognized medical uses, and thus can be prescribed, administered, or dispensed. These tight regulations have given rise to an illegal market, where prescription drugs are diverted for abuse.¹⁶

In 2011, the Centers for Disease Control and Prevention classified prescription drug abuse in the U.S. an epidemic. The most commonly abused prescription drugs include central nervous system depressants, stimulants and in particular, opioid pain

¹⁴Alcohol and tobacco are not considered controlled substances.

¹⁵The increasing order of the schedules reflects progressively less dangerous substances. Examples of controlled substances in schedules I, II, III and IV are heroin, oxycodone, buprenorphine, and alprazolam, respectively.

¹⁶Prescription drugs are diverted through various channels which include doctor prescriptions, doctor-shopping, pharmacy, hospital, or doctor office theft, medicine cabinet theft, and the internet.

relievers. In 2013, an estimated 4.5 million or 70% of Americans aged 12 or older who were past-month non-medical users of prescription drugs reported using opioid pain relievers (NSDUH, 2014).¹⁷ Drugs within this class work by binding the opioid receptors and may cause side effects such as sedation, respiratory depression, constipation, and euphoria. With continued use, physical and psychological dependence can develop, leading to withdrawal syndrome with abrupt discontinuation. Opioids are often snorted or injected and co-abused with benzodiazepines, a type of CNS depressant, to enhance the euphoric high (Jones et al., 2012). Oxycodone, a schedule II opioid and the active ingredient in commonly prescribed medications such as Percocet and Oxycontin, is favored among non-medical users for its euphorogenic effects (Cicero et al., 2013). In 2013, the U.S. share of global oxycodone consumption stood at 78% (INCB, 2014). Opioid pain reliever sales have increased dramatically over the last decade and alongside, so have the social costs associated with their abuse.¹⁸

The main social costs of drug abuse comprise the internal and external costs of health, crime, and labor productivity losses. Health costs include those from morbidity and mortality, and the healthcare expenditures incurred in addressing their harm. The prevalence and incidence of these costs in the context of opioid pain relievers is well documented. Overdose deaths involving opioid pain relievers increased by 303% from 4,030 in 1999 to 16,235 in 2013 (CDC, 2015); emergency department visits involving non-medical use of opioid pain relievers increased by 183% from 172,738 in 2004 to 488,004 in 2011 (DAWN, 2013); the rate of newborns with Neonatal Abstinence Syndrome increased from 1.20 to 3.39 per 1000 hospital

¹⁷The number of estimated non-medical users of psychotherapeutic tranquilizer, stimulant and sedative drugs in 2013 was 1.7, 1.4 and .251 million, respectively (NSDUH, 2014).

¹⁸Birnbaum et al (2011) estimate that in 2007 the social costs of prescription opioid abuse amounted to \$55.5 billion. Healthcare, criminal justice and workplace costs accounted for 45%, 9% and 46% of total costs, respectively.

births from 2000 to 2009 (Patrick et al., 2012); and in 2015, an HIV outbreak linked to injection of opioid pain relievers took place in Indiana (CDC, 2015).¹⁹ Insurance fraud is another source of health costs, especially among social healthcare programs (Mack et al, 2015; GAO, 2009; CAIF, 2007). Costs to insurers exceed those from drug purchases as abusers incur in additional services such as doctor and hospital visits. A study analyzing Medicaid claims in search for indicators of potential inappropriate use or prescribing of opioids among enrollees found that 40% of recipients had at least one such indicator (Mack et al, 2015).

The crime costs of drug abuse arise from three main channels. First, drug's pharmacological effects may increase aggression and thereby, crime. Second, users may turn to crime to finance their addiction (Goldstein, 1985). Third, the drug abuse lifestyle may predispose criminal activity by offering opportunities to offend resulting from skills learned from other offenders and illegal markets (NIDA). Evidence regarding the crime costs of prescription opioid abuse is largely anecdotal. According to newspaper articles and DEA reports, these costs include stealing medications from legitimate users or suppliers, doctor shopping, insurance fraud, and other common criminal activity such as property and violent crimes. The magnitude of these offenses, however, is unknown. Previous studies have documented a strong link between crime and heroin, an illegal drug opioid.²⁰ It is unclear whether these results apply to opioid pain relievers.

To curb opioid abuse, the Office of National Drug Control Policy implemented

¹⁹As of April 21, Indiana State Department of Health (ISDH) had diagnosed HIV infection in 135 persons (129 with confirmed HIV infection and six with preliminarily positive results from rapid HIV testing that were pending confirmatory testing) in a community of 4,200 persons.

²⁰A study surveying Scottish prisoners and non-prisoners found that heavy opioid users committed crimes significantly more frequently than did moderate opioid users, non-opioid poly drug users, cannabis users or alcohol users. But, moderate opioid users did not commit crimes significantly more frequently than did the other groups (Hammersley et al, 1989)

the Prescription Drug Abuse Prevention Plan, which expands upon the National Drug Control Strategy and includes action in four major areas: education, monitoring, proper disposal, and enforcement. Education intends to raise awareness among the public and healthcare providers. Monitoring through Prescription Drug Monitoring Programs, a statewide electronic database which collects data on dispensed substances, can help to identify "doctor shoppers". Drug disposal programs may help to limit the diversion of drugs, since many non-medical users obtain the drugs from family and friends. Finally, enforcement can help tackle prescribing outside the usual course of practice. While previous studies have documented the impact of prescription drug abuse control strategies such as treatment or monitoring programs, little is known about the effect of supply-side interventions such as enforcement.

Despite significant societal costs associated with prescription drug abuse, previous studies have focused on the enforcement of illegal drugs. Theoretical work predicts that under enforced prohibition, the price of drugs will exceed that under legalization due to larger production costs from avoidance efforts, the expected value of confiscated drugs, and the expected costs of punishment (Becker, Grossman & Murphy, 2006). Marginal increases in enforcement raise a supplier's probability of conviction and thus, production costs. In turn, equilibrium prices should increase and quantities should decrease (under any elasticity of demand). Empirical evidence is mixed. While prohibition seems to raise prices above those likely to pertain under legalization, most studies of the impact of marginal increases in supply-side enforcement find no effects, or at best, modest or temporary effects.^{??} National trends are also puzzling. Over the last decades of the twentieth century, drug prohibition enforcement, measured as federal budget and drug arrests, expanded dramatically in the U.S. Meanwhile, purity-adjusted prices of cocaine and heroin more than halved (Basov, Jacobson & Miron, 2001; Boyum & Reuter, 2005). The existing evidence

may not generalize to prescription drugs, which have accepted use in medical treatment and thus, are legally produced by DEA registered suppliers.

To assess the question of prescription drug supply-side intervention effectiveness, the social costs and benefits associated with the intervention's implementation must be considered. While benefits can include reductions in drug abuse and its associated adverse outcomes, costs can include criminal justice expenses from enforcement and punishment. Moreover, if demand is inelastic, consumer expenditures on drugs and supplier's resources devoted to drug production can increase, which in turn, may result in a rise in criminal activity.²¹ In this paper, a large number of outcomes that proxy for some of these benefits and costs are examined. Another source of costs from prescription drug supply-side enforcement is that legitimate medical users might have a harder time gaining access to treatment. Due to data limitations, this paper will not address such issue.

2.2 The Florida Pill Mill Crackdown

By the late 2000s, Florida had become the epicenter of America's prescription drug abuse epidemic and oxycodone the drug in demand. Florida was a major supplier of diverted prescription drugs for people from in and out of the state.²² Practitioners prescribing and dispensing from pain management clinics, referred to as "pill mills", were a main source of diversion. Pill mill operations were known for the inappropriate prescribing and dispensing of controlled substances, nearly exclusive associations with specific pharmacies, cash-based payment methods, and casual examinations.

²¹Criminal activity can increase due to abusers trying to finance their now more expensive addiction or from increased black-market violence. Black-market violence may occur from increased prescription drug theft or from increased demand for illegal drugs. Illegal suppliers cannot rely on contracts and courts to resolve disputes (Goldstein, 1985).

²²The most cited states include Georgia, Kentucky, Tennessee, Ohio, Massachusetts, New Jersey, North and South Carolina, Virginia and West Virginia.

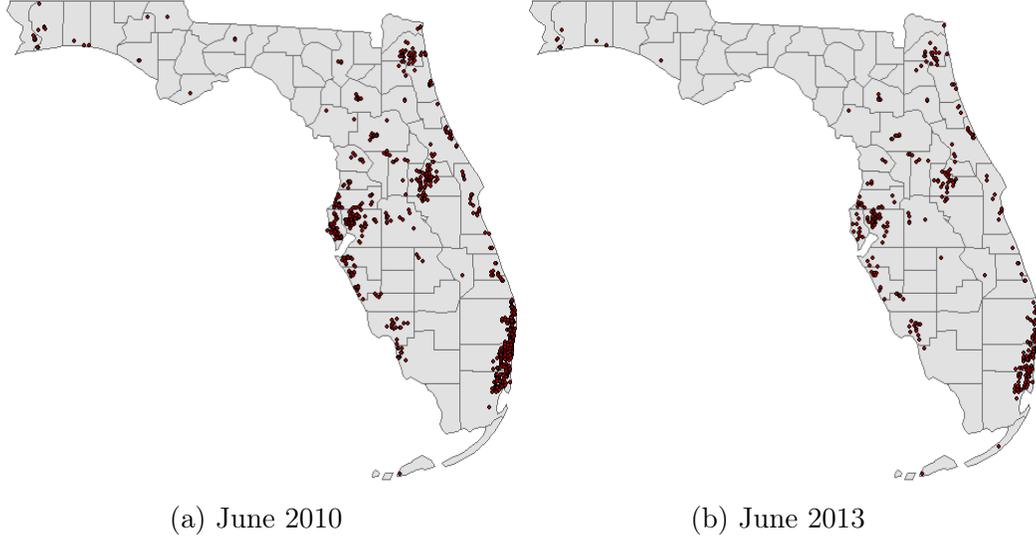


Figure 1: Pain Clinic Active Licenses in Florida

Notes: Figure is constructed using Licensure data collected by Florida’s Department of Health. Location addresses are geocoded and spatially linked to U.S. Census Cartographic Boundary files for Florida using GIS.

Pill mills proliferated in South and Central Florida.²³ In mid-2010, law enforcement and legislative officials initiated a sweeping crackdown on Florida pill mill suppliers. These included wholesale distributors, pain-management clinics, pharmacies, pharmacists and practitioners (physicians, dentists, veterinarians, osteopathic physicians, naturopathic physicians, and podiatrists). There were two key aspects to this crackdown: enforcement and legislative action.

Enforcement consisted of a series of investigations dubbed Operation Pill Nation that were led by the Drug Enforcement Administration in joint effort with state

²³According to Pain Management Clinic Licensure data, Broward, Hillsborough, Miami-Dade, and Palm Beach counties accounted for approximately 45% of all Florida pill mills. These counties also happened to contain most of the top practitioners dispensing oxycodone in the United States. Broward County alone contained half of the top dispensing practitioners who were responsible for 55.4% of total units of oxycodone dispensed in the country during the period of October 2008 to March 2009.

and local law enforcement authorities. These resulted in the surrender, suspension, revocation, or denial of the state medical license/ DEA Certificate of Registration of diverting healthcare providers, namely, physicians, pharmacists, pharmacies and pain clinics. Either temporarily or permanently, suppliers could no longer handle controlled substances. Another component of the strategy for Operation Pill Nation was to identify the wholesale distributors that were supplying controlled substances to pill mills. In June 2010, DEA took administrative action against four such wholesale distributors (DOJ, 2011).

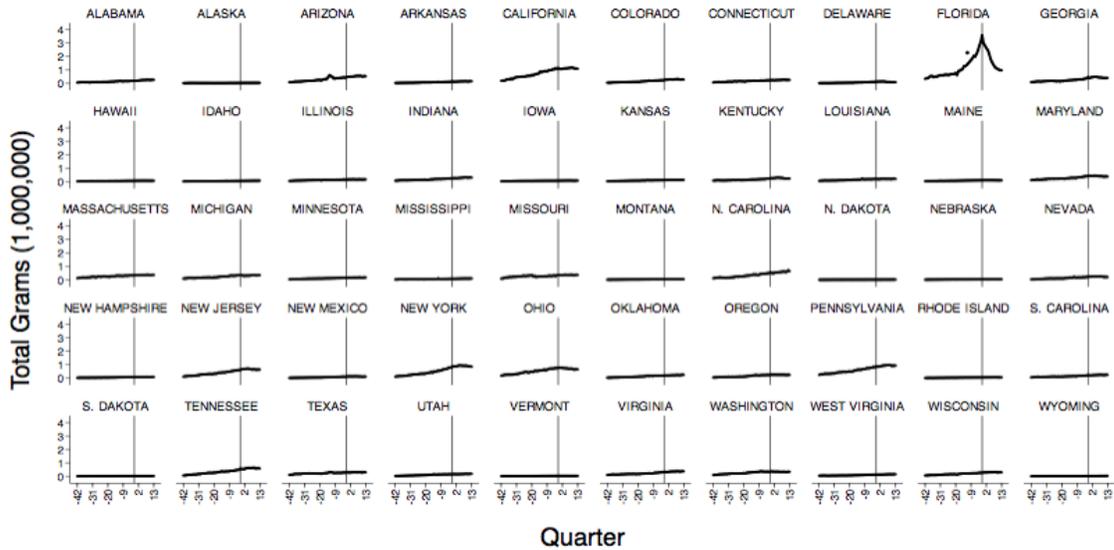


Figure 2: Quarterly Oxycodone Supply by State 2000-2013

Notes: Figure is constructed using ARCOS Report 2 data.

Legislative action (bills SB 2272 and HB 7095) targeted pain clinic suppliers in a variety of ways, but most notably by amending Dispensing Practitioner Laws (Florida Statute 465.0276).²⁴ The amendment was first enacted in June 2010 and

²⁴Other notable feature of these laws included requiring pain clinics to register with the Florida

became effective in October of 2010. Additional elements became effective in July, 2011. Before these changes, authorized Florida practitioners were allowed to prescribe and dispense controlled substances in schedules II-V. SB 2272 amended the law by dictating that practitioners working from pain clinics could only dispense up to a 72-hour supply of controlled substances in schedules II-V to a patient paying in cash, check, or credit card.²⁵ In July 2011, HB 7095 expanded upon these efforts by dictating that practitioners could no longer dispense controlled substances in schedules II & III.

Either through enforcement or legislative action, the aim of the pill mill crackdown was the same: to revoke diverting legal suppliers' ability to dispense or prescribe controlled substances. The pill mill crackdown resulted in a massive shutdown of Florida's pain clinics. From 988 pain clinic active licenses in June 2010, only 376 were still active in June 2013, a 62% decline (see Figure ??). This led to the largest state-level shock to oxycodone supply in over a decade (see Figure ??).²⁶

3 Empirical Strategy

3.1 Data Sources

This paper examines a wide number of outcomes, including prescription drug quantities, street prices, total suppliers, deaths, inpatient and outpatient hospital discharges, pain management clinic licenses, property crime, violent crime, drug arrests, drug theft, full-time police and substance abuse treatment admissions. Out-

Department of Health. Note, however, that any physician operating in these clinics, and in Florida more generally, was already required to be registered with the DOH and the DEA.

²⁵The law excluded practitioners dispensing to workers compensation patients or insured patients paying a copay or deductible in cash, check, credit card.

²⁶Furthermore, DEA data suggest the intervention resulted in the largest state-level drop in *opioid* supply during the sample period.

comes are drawn from sixteen datasets collected by novel administrative and online sources. With the exception of crime data, outcomes based on administrative sources represent a near census of events.

Drug street price data are drawn and pooled from two websites, StreetRx.com and Bluelight.org, both of which rely on crowd sourcing.²⁷ The former is available from 2010-2013, while the latter is available from 2008-2010. Variables include drug name, date of post, price, mg strength, formulation, city, and state. Date of post is used as a proxy for date of purchase. This joint dataset has two weaknesses worth noting. First, the prices are likely not representative of all drug street prices because only abusers who participate on these websites report. Second, for some drug-quarters there are few or no observations reported. Still, this data can be informative of the street prices faced by the reporting population, which might resemble that of the general population.

Quantities, measured in grams, are drawn from DEA's Automation of Reports and Consolidated Orders System (ARCOS), a drug reporting system that monitors the flow of controlled substances from their point of manufacture through commercial distribution channels to point of sale or distribution at the dispensing/retail level. ARCOS' Reports 2 and 5 are used in this study, both of which provide total grams purchased by hospitals, pharmacies, practitioners, mid-level practitioners, narcotic treatment programs and teaching institutions. Both reports cover sales for each U.S. state, by controlled substance, for substances in schedules I & II and selected substances in schedule III, and are available from 2000-13. The main distinction between these sources is that Report 2 identifies total sales at the year-quarter level, while

²⁷Bluelight includes in its message board a series of annual price threads where members of the community post drug street prices in their city. Since the information is contained in messages rather than a usable format, a dataset had to be constructed by reading each post, and selecting those that identified Florida.

Report 5 identifies total sales at the year level, with totals broken by provider type. Total suppliers data are also drawn from ARCOS' Report 5. This outcome captures the total number of providers that were purchasing controlled prescription drugs, by controlled substance, state, and provider type (e.g. total practitioners purchasing oxycodone in Florida). Grams and buyers data for morphine, hydromorphone and fentanyl is not reported for the year 2012. To circumvent this issue, total grams missing values are imputed using ARCOS dosage units data, which was reported in 2012, and average grams per dosage units in 2011 and 2013.²⁸ As for total buyers, missing values are imputed using the average value in 2011 and 2013.²⁹ There are two instances in which an outlier value is dropped and inputed with the average amount in the previous and following date. See Appendix for details.

Drug-related deaths are drawn from toxicology reports submitted to Florida's Medical Examiners Commission. This dataset reports drugs identified in deceased persons for 50 monitored drugs and distinguishes between drugs that were merely "present" in the body or the "cause" of death. Individual-level data are available for Florida, by county, month and active ingredient. The identification of active ingredient allows for a closer examination of substitute and complement drugs. Although data are available from 2007 to 2013, counties are identified starting in 2009.

Inpatient and outpatient hospital discharges are drawn from the Florida Agency for Healthcare Administration. Individual-level data are available for Florida, from 2008-2012, by county, quarter and drug class. The main variables are "admitting diagnosis", "principal diagnosis", "other diagnosis" and "external cause of injury", which are based on ICD-9-CM codes. To identify admissions primarily caused by drug abuse, the variables "admitting diagnosis" and "principal diagnosis" are used.

²⁸ $imputedgrams_{2012} = dosageunits_{2012} * mean(grams/dosageunits)_{2011,13}$

²⁹ $imputedbuyers_{2012} = mean(buyers)_{2011,13}$

Selected individuals include those with the following ICD-9-CM codes: 304 Drug dependence; 305.2-305.9 Nondependent abuse of drugs; 292 Drug-induced mental disorders (includes withdrawal); and 960-979 Poisoning by drugs (includes overdose). Conditional on being admitted for these diagnoses, drug class is selected using "admitting diagnosis", "principal diagnosis", "other diagnosis" and "external cause of injury" variables. Unlike other outcomes, these datasets identify drug class rather than active ingredient, making it impossible to report estimates for the previously established drug groups. The opioid class, which includes oxycodone, NTPs, substitutes, heroin and others uses the codes 304.0, 304.7, 305.5, 965.0, E850.0, E850.1, E850.2, E935.0, E935.1, and E935.2. The benzodiazepine class, which includes complements, uses the codes 304.1, 305.4, 969.4, E853.2 and E939.4. Amphetamine uses the codes 304.4, 305.7, 969.72, E854.2 and E939.7. The cannabis class, which includes marijuana, uses the codes 304.3, 305.2, 969.6, E854.1 and E939.6. Cocaine, an illicit drug stimulant, uses the codes 304.2, 305.6, 970.81, E855.2 and E938.5. Heroin, an illicit drug opioid, uses the codes 965.01, E850.0 and E935.0.

Pain Management Clinic licensure data are drawn from Florida's Department of Health. Firm-level data reports the exact date a license was first granted, revoked or relinquished, practice name, and practice location address. Data are available from late 2009-2013. License dates are used to proxy market entry and exit. Exact location addresses are geocoded and spatially linked to U.S. Census Cartographic Boundary files for Florida using Geographical Information Systems (GIS).

Index crime data are drawn from the Florida Department of Law Enforcement's (FDLE) Uniform Crime Reports (UCR) Program. UCR numbers reflect the crimes reported by the local agencies (e.g. Sheriff Offices and Police Departments) to FDLE. This system provides standardized reports on property and violent crime as well as drug arrest statistics by year and county. Nation-level UCR data on property

crimes, violent crimes and drug arrests is also used in the analysis. This data are drawn from the Federal Bureau of Investigation (FBI) and is available by year and state. Full-time police data are also collected by the FBI and is available by year and state. FDLE and FBI datasets are available up to 2013. Armed Robbery and Night Break-In counts are drawn from the Drug Theft or Loss data collection system, in which registrants report their controlled substance losses to the DEA. This data are available from 2009-2013, by year, county and state. A known drawback of crime data is that its based on reported events rather than actual events.

Substance abuse treatment admissions are drawn from the National Survey of Substance Abuse Treatment Services (NSSATS). NSSATS is a point-prevalence survey. It provides information on the substance abuse treatment system and its clients on the reference date, March 30. Client counts do not represent annual totals; instead, NSSATS provides a "snapshot" of substance abuse treatment facilities and clients on an average day. NSSATS collects data about facilities, not individual clients. Data on clients represent an aggregate of clients in treatment for each reporting facility. NSSATS attempts to obtain responses from all known treatment and prevention facilities, but it is a voluntary survey. Data are available at the facility level, identifies county, is collected annually up to the year 2012, and has a reference date of March 30.

3.2 Econometric Approach

The empirical approach is to compare changes in outcomes in areas that were most affected by the epidemic to those in areas that were less affected. Naturally, epidemic intensity is not randomly assigned as affected areas might differ in level or growth of socio-economic status, population characteristics, and health care utilization. Therefore, the strategy is to test for level or trend breaks in pre-existing

differences in outcomes after the pill mill crackdown in mid-2010, which resulted in the largest state-level drop in oxycodone supply in over a decade (see Figure ??). The identifying assumption is that absent the intervention, pre-period differences would have continued on the same trends.

The basic econometric specifications are depicted below. Equation ?? is a linear spline specification that estimates the slope and intercept deviations between treatment and control groups, before and after the intervention. Figure ?? Equation ?? is a difference-in-differences specification that estimates the overall effect of the intervention. All outcomes of interest y_{gt} are in logs as these are based on count data and reflect variation in the size of the unit of observation. To avoid the loss of observations with count of zero, 1 is added to all outcomes. The treatment group $Treatment_g$, post period $Post_t$, time trend $Trend_t$, location fixed effects G_g , and year fixed effects Y_t are indexed by geographic unit g and time period t . For consistency across datasets and due to the imposition of a linear trend, the sample is restricted to the years 2008-2012. Standard errors are clustered at the geographic unit level.

$$\begin{aligned}
 \ln(y_{gt}) = & \alpha_0 + \alpha_1 Post_t * Treatment_g + \alpha_2 Trend_t + \\
 & \alpha_3 Trend_t * Treatment_g + \alpha_4 Trend_t * Post_t + \\
 & \alpha_5 Trend_t * Post_t * Treatment_g + G_g + Y_t + \epsilon_{gt}
 \end{aligned} \tag{1}$$

$$\ln(y_{gt}) = \beta_0 + \beta_1 Post_t * Treatment_g + G_g + Y_t + \epsilon_{gt} \tag{2}$$

Data limitations condition the choice of counterfactual as some outcomes are

available for all U.S. states, while others are available for the state of Florida only. When data are available for all states, outcomes in Florida are compared to those in other states, in which case $Treatment_g$ is a dummy variable equal to one for Florida and zero otherwise, and G_g are state fixed effects. In Equation ??, α_1 and α_5 indicate the differential intercept and slope effect experienced by the treatment group after the intervention. In Equation ??, β_1 identify the overall shift experienced by the treatment group after the intervention. One might be concerned that spillovers could threaten cross-state estimates if the intervention induced users to seek oxycodone elsewhere, causing supply in other states to increase by a similar amount to the decline witnessed in Florida. To examine this possibility, Figure ?? plots total oxycodone grams by state.³⁰ There seems to be no evidence in support of this theory.³¹ These spillovers could also happen across drugs if oxycodone users substitute to other opioid pain relievers. Again, Figures ?? and ?? show no evidence in support of this theory.

When data are available for the state of Florida only, outcomes in pill mill counties are compared to outcomes in the rest of the state. This geographic variation can be observed in Figure ??, which plots pain clinics into a Florida map using geocoded location address from licensure data. Here, $Treatment_g$ is a continuous variable that represents total pain management clinics per capita in the county pre-intervention (see Subfigure ??), and G_g are county fixed effects. One might be concerned that nation-wide factors affected prescription drug supply in Florida.³² Again, Figures ??,

³⁰Absolute magnitudes rather than per capita values are plotted to detect the magnitude of these spillovers. Figures ?? and ?? show per capita values.

³¹In fact, some states see a slowdown in oxycodone supply growth, especially in 2013. This year, however, is excluded from the regression analysis.

³²Examples of such forces include changes in Aggregate Production Quotas, National Prescription Drug Take-Back Days or Drug Shortages. Another nation wide intervention worth noting was a change in the controlled-release formulation of OxyContin (oxycodone brand name produced by Purdue Pharma), which took place in August 2010. The new tablet was designed so that it cannot

?? and ?? show minor evidence in support of this story. One cannot assume that the geographic location of supply maps that of demand as Floridians from all counties likely traveled to the pill mills. This implies that Floridians as a whole, would be affected by the epidemic and subsequent interventions. Nonetheless, transaction costs from traveling and searching should be lower for pill mill county residents, making their optimal pre-period consumption higher.³³ Thus, cross-county estimates $\beta_1, \alpha_1, \alpha_5$ can be interpreted as the heterogenous treatment effect for pill mill counties, an analysis that provides further evidence of the link between changes in outcomes and the pill mill crackdown by showing that those who should have been most affected indeed were.

To strengthen the interpretation of the findings, estimates are classified into groups based on active ingredients and its relation to oxycodone. These include oxycodone, prescription drug substitutes, illegal drug substitutes, prescription drug complements, narcotic treatment program (NTP), other illicit drugs, and prescription drug stimulants.³⁴ Prescription drug substitutes include other schedule II or III opioid pain relievers not used for opioid abuse treatment. Illegal drug substitutes include other schedule I opioids. NTPs include other schedule II or III opioid pain relievers used in opioid abuse treatment. Prescription drug complements include schedule IV benzodiazepines that tend to be abused in conjunction with opioid pain relievers. Prescription drug stimulants are scheduled II prescription drugs with potential for abuse but not associated with the painkiller epidemic. Thereby, stimulants were directly affected by the laws but indirectly affected by enforcement, while

be easily broken, chewed, crushed, or dissolved.

³³This is especially true as prescriptions for controlled substances in schedule II cannot be refilled, and although practitioners can issue multiple prescriptions, the combined effect of these cannot exceed a 90-day supply.

³⁴See appendix for a detailed description of the drugs in these groups.

complements experienced the opposite effect. This analysis can shed light on the contribution of dispensing practitioner laws relative to that of enforcement.

4 Results

4.1 Drug Availability

This section analyzes the impact of supply-side interventions on prescription drug availability as measured by quantities and street prices. Either through a supply shortage or a price increase, a successful intervention should reduce total oxycodone quantities sold. The effect on overall opioid pain reliever supply is unclear a priori as it depends, among other things, on the extent to which substitute drugs were directly or indirectly affected by the crackdown.³⁵ If directly affected, the supply of other opioid pain relievers should decrease. If not directly affected, the supply of other opioid pain relievers could increase if oxycodone's shock generates an upward demand shift towards these drugs.

4.1.1 Prescription Drug Quantities

Figure ?? plots potency adjusted grams per capita by drug group for Florida and the U.S.³⁶ During the early 2000's, Florida's opioid pain reliever supply evolved like that in the rest of the country. In late 2006, however, Florida's oxycodone supply began to rise sharply, while substitutes continued on the same trends.³⁷ In mid-2010,

³⁵Amendments to dispensing practitioner laws targeted not only oxycodone, but also controlled substances in schedules II & III. This is also true in the case of enforcement because when a DEA registration is revoked, no controlled substances can be handled. Nonetheless, if deviant doctors were primarily diverting oxycodone, then a shock to healthcare providers will have a small effect on other opioid pain relievers. The supply of other opioid pain relievers might even increase if doctors begin to prescribe less targeted drugs.

³⁶Note that stimulants are not potency adjusted as these are not opioid drugs.

³⁷An outlier value in the fourth quarter of 2007 can be observed across all controlled substances in the state of Florida. It is unclear whether this figure represents a true amount or is the result of

Florida’s oxycodone supply faced an abrupt drop, followed by a steady decline that reached national levels in 2013. There is no evidence of a supply recovery or of substantial spillovers across states (see Figure ??) or other opioid pain relievers (see Subfigure ??).

Table ?? reports estimates for log grams by drug group using Equation ??, where $Treatment_g$ is a dummy variable equal to one for Florida and zero otherwise. The last two columns replicate the analysis for potency adjusted grams as described in the appendix. This specification allows Florida’s trend to be differentially affected by the crackdown and adjusts for nation-level interventions that might have also occurred during the post-period. Pre-crackdown, the growth rate of quarterly oxycodone supply in Florida was approximately six percentage points higher than that in the rest of the country. Meanwhile, the growth rate of unadjusted supply for other drug groups in Florida was approximately the same as that in the rest of the country, and one percentage point lower for potency adjusted grams.

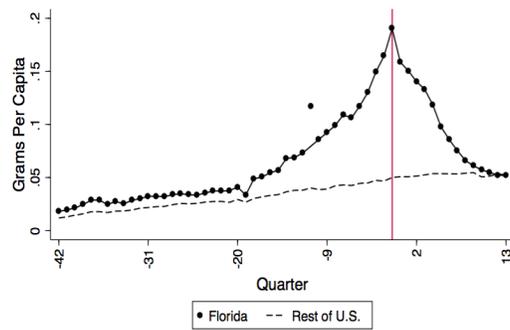
Post crackdown, the growth rate of quarterly oxycodone supply in Florida was approximately eighteen percentage points lower than that of the control group. This difference is statistically significant. Between 2010-12, average oxycodone and substitute supply in Florida was 59% lower and 3% higher than what it would have been absent the crackdown. The percentage change in supply between Florida and the control group at different points in time is also depicted in the table.

When re-calculating the percentage change between average oxycodone supply in Florida and that of the control group, but assuming that in the absence of the crackdown Florida would have continued on its pre-period trends,³⁸ I find a reduction

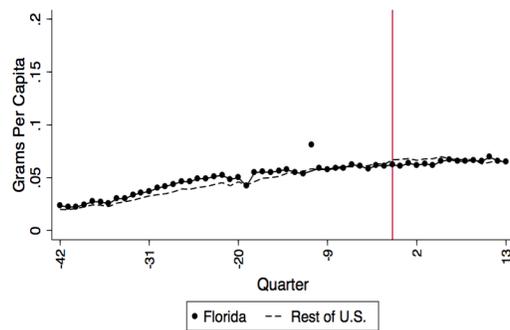
error. This outlier is recorded consistently throughout all of ARCOS datasets, but its not observed in consumption data such as medicaid claims, hospitalizations or drug deaths.

³⁸That is, not adjusting for potential effects from nation-level interventions as reported in Table ??.

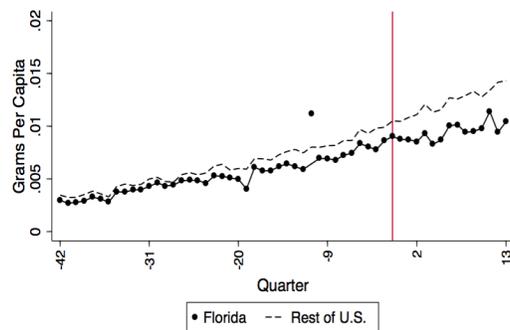
of 62% (only slightly more negative than 59%). This provides additional evidence (beyond graphical evidence from Figure ??) that nation-level interventions are not driving the results in Florida.



(a) Oxycodone



(b) Substitutes



(c) Stimulants

Figure 3: Quarterly Prescription Drug Supply (2000-2013)

Notes: Figure is constructed using ARCOS data. Outcome represents total grams purchased by suppliers for retail sales in each drug group. Total grams are divided by 2010 population estimates and adjusted for potency as described in the appendix. Substitute and stimulant drugs are described in the econometric approach and appendix sections. Gram totals for morphine, hydromorphone, and fentanyl are not reported and thus imputed in 2012 (see data section).

Table 1: Log Prescription Drug Grams (2008-2012)

	Unadjusted				Adjusted		
	Oxycodone	Substitutes	NTP	Stimulants	Substitutes	NTP	NTP
<i>Florida</i> \times <i>Trend</i>	0.06*** (0.00)	-0.00 (0.00)	-0.00 (0.00)	0.00 (0.00)	-0.01*** (0.00)	-0.01*** (0.00)	-0.01*** (0.00)
<i>Florida</i> \times <i>Trend</i> \times <i>Post</i>	-0.18*** (0.00)	0.01*** (0.00)	-0.05*** (0.00)	-0.01*** (0.00)	0.02*** (0.00)	-0.01*** (0.00)	-0.01*** (0.00)
<i>Florida</i> \times <i>Post</i>	-0.10*** (0.01)	-0.03*** (0.01)	0.09*** (0.01)	-0.05*** (0.01)	-0.04*** (0.01)	0.06*** (0.01)	0.06*** (0.01)
R^2	1.00	1.00	0.99	1.00	1.00	1.00	1.00
N	1020	1020	1020	1020	1020	1020	1020
<i>Florida Pre-Mean</i> (1,000)	2339	1186	372	145	1130	1691	1691
% Δ	-59.30	0.48	-10.01	-9.48	3.13	1.52	1.52
% Δ at <i>Trend</i> = 0 (Q3 2010)	-9.77	-2.50	9.78	-4.63	-4.40	6.55	6.55
% Δ at <i>Trend</i> = 1 (Q4 2010)	-24.98	-1.85	4.67	-5.69	-2.77	5.41	5.41
% Δ at <i>Trend</i> = 5 (Q4 2011)	-64.14	0.80	-13.49	-9.81	3.99	0.98	0.98
% Δ at <i>Trend</i> = 9 (Q4 2012)	-82.86	3.51	-28.50	-13.76	11.23	-3.26	-3.26

State clustered standard errors are in parenthesis. Figure is constructed using ARCOS Report 2 data. See Appendix for drugs in each group. Gram totals for morphine, hydromorphone, and fentanyl are not reported in 2012. These values are imputed combining dosage units totals, reported in 2012, and average grams per dosage unit in 2011 and 2013 (see data section). The post-period starts in the third quarter of 2010 (Trend=0). For % Δ at *Trend* = t use $100 \times (e^{(\alpha_1 + \alpha_5 \times t)} - 1)$.

4.1.2 Prescription Drug Street Prices

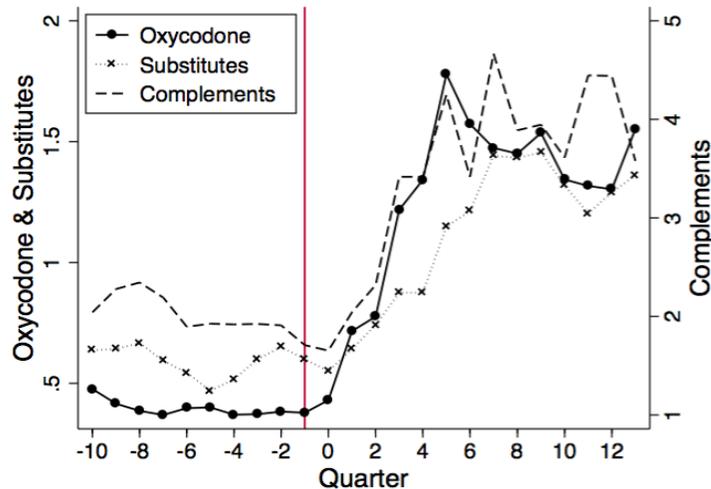


Figure 4: Quarterly Street Prices per Milligram in Florida (2008-2013)

Notes: Figure is constructed using BlueLight and StreetRx data. Outliers are dropped. Complement and substitute categories consist of alprazolam and hydrocodone, respectively. Data points are a moving average that incorporates previous, current, and following quarter’s price per milligram. Quarters with missing data are imputed with year average for substitutes. Milligrams are adjusted for potency as described in the appendix.

Figure ?? plots prescription drug street prices per milligram for oxycodone, its complement alprazolam and its substitute hydrocodone.³⁹ Note that these prices do not reflect the prices directly paid to dispensing physicians or pharmacies. Pre-intervention, oxycodone, complement and substitute street prices were stable. Post-intervention, street prices increased by 238%, 114% and 140%, respectively (see Table ??). At a first glance, these results might seem conflicting with economic theory which wouldn’t predict a price increase for oxycodone’s complements. Note, however, that alprazolam was being dispensed and prescribed jointly with oxycodone

³⁹There is not enough data on other substitute drugs to analyze the average price change for this group.

from the pill mills, and although its supply wouldn't be affected by the dispensing laws, it would be directly affected by enforcement.⁴⁰ Indeed, a closer examination of Medicaid claims data reveals that alprazolam was in scarcity post-intervention. These results suggest that enforcement was effective at reducing street availability. Nonetheless, survey data suggests that the prescription drug street market is small and thus, these prices may not be representative of the average prices paid by non-medical users.⁴¹

Table 2: Street Prices Per Milligram (2008-2012)

	Unadjusted			Adjusted
	Oxycodone	Substitutes	Complements	Substitutes
<i>Difference</i>	0.96***	0.55***	2.31**	0.83***
<i>P – Value</i>	0.00	0.00	0.03	0.00
<i>Pre – Mean</i>	0.40	0.39	2.04	0.59
<i>Post – Mean</i>	1.36	0.95	4.35	1.42
<i>N</i>	220	49	55	49
<i>%Δ</i>	238.48	140.74	113.55	140.74

Tables created using StreetRx and Bluelight Data. Outliers are dropped. Complement and substitute categories consist of alprazolam and hydrocodone, respectively. In the last column, milligrams are adjusted for potency as described in the appendix.

4.2 Drug Abuse and Public Health

This section analyzes the impact of supply-side interventions on prescription drug non-medical consumption and public health as measured by deaths, hospitalizations, and substance abuse treatment admissions. The previous section found a substantial decline in Florida's oxycodone supply and no substantial oxycodone or substitute

⁴⁰Alprazolam is a schedule IV controlled substance

⁴¹According to the 2013 NSDUH, in only 4.3% of the cases, drug dealers were the source where pain relievers were obtained in 2012-13 for most recent non-medical use among past year users aged 12 or older.

spillovers across states. If non-medical users manage to find these drugs through illegal suppliers, opioid pain reliever consumption might not match supply. Specifically, depending on illegal supplier opioid pain reliever availability, consumption might not even be affected by the intervention. However, if in fact legal suppliers rather than illegal ones are the original source of most diverted prescription drugs, then Florida's oxycodone consumption should decline. More generally, then one would expect changes in prescription drug supply to translate into similar changes in prescription consumption in this context. The effect on illegal drug substitutes remains to be explored. Since illegal drugs were not targeted by the intervention, economic theory predicts that a negative shock to oxycodone supply would result in a positive shock in the demand of illegal drug substitutes.

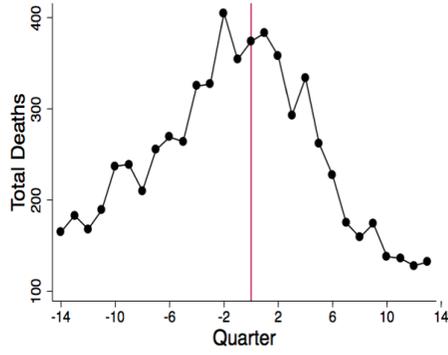
4.2.1 Deaths

Figure ?? plots total instances in which a given drug played a casual role in the death of a person. Subfigure ?? shows that declines in oxycodone quantities were followed by substantial declines in overdose deaths. Complement drugs also displayed substantial declines in overdose deaths. Substitute and stimulant drug deaths continued on its pre-intervention trends. Deaths by heroin, an illegal drug substitute, began to increase post-intervention, although the magnitude of this increase is small. These deaths have received considerable media attention given a recent national spike in heroin overdose deaths anecdotally attributed to initial prescription opioid abuse.

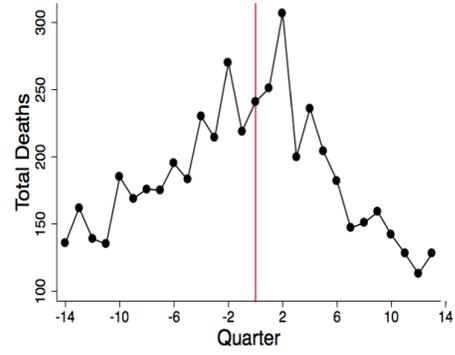
Table ?? reports results from Equation ??, where $Treatment_g$ is a continuous variable that represents the total pain management clinics per capita in the county pre-intervention. During the epidemic, oxycodone and complement deaths increased in pill mill counties, while those from heroin decreased. Other prescription and illicit

drugs were stable. Post-intervention, oxycodone and complement deaths decreased while heroin deaths increased more in pill mill counties. Deaths from other illicit drugs are statistically insignificant. Note that the coefficients for counties with zero pill mills are all statistically insignificant. Estimates can be interpreted more meaningfully by considering pill mills per capita in a given county. Take for instance Broward county, a main hot spot for drug diversion at the time, with .0000761 pill mills per capita. Prior to the intervention, the growth rate of quarterly oxycodone deaths in Broward county was 10%.⁴²

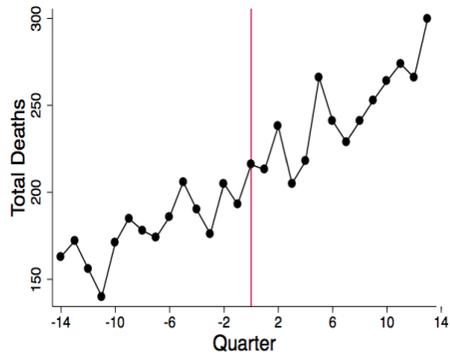
⁴²(100 × [(0.00) + (1262.7) × .0000761=.0960382])



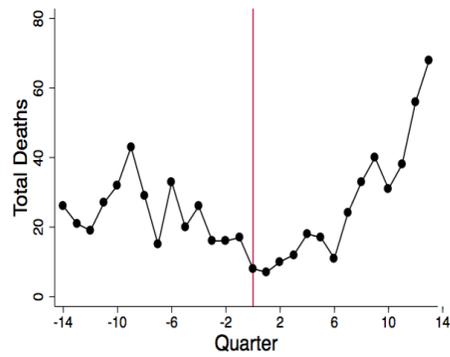
(a) Oxycodone



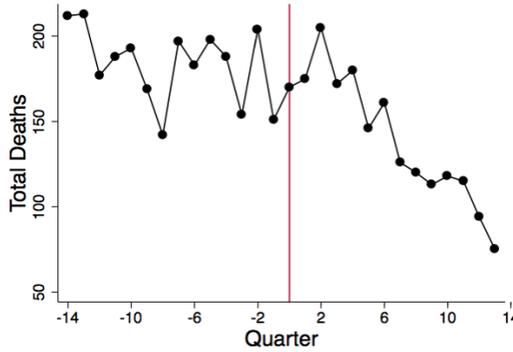
(b) Complements



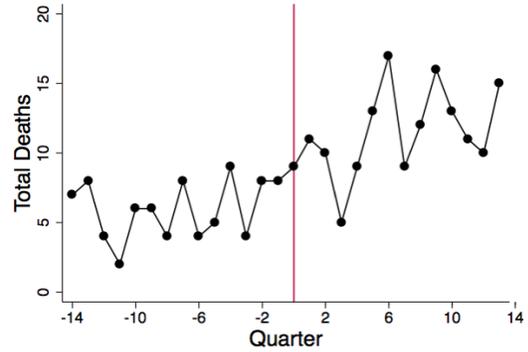
(c) Substitutes



(d) Heroin



(e) NTP



(f) Stimulants

Figure 5: Causal Role in Death (2007-2013)

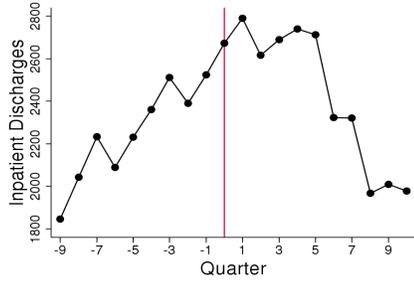
Notes: Figure is constructed using Florida's Medical Examiners Commission data. Counts include deaths in which the named drug had a causal role.

Table 3: Log Deaths (2009-2012)

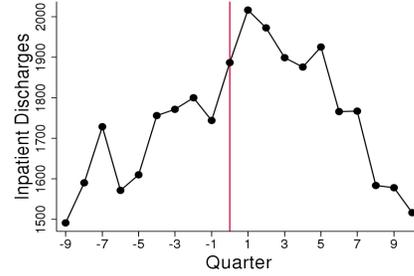
	Oxycodone	Substitute	NTP	Heroin	Complement	Stimulant	Cocaine
$PMC \times t$	1262.78*** (428.26)	335.26 (342.59)	548.36 (405.54)	-368.55 (229.43)	929.14** (395.75)	-123.62 (261.94)	47.69 (310.39)
$PMC \times t \times Post$	-2552.89*** (520.20)	-190.63 (416.39)	-1015.99*** (363.09)	941.49*** (321.38)	-1922.89*** (473.48)	224.29 (269.30)	-104.60 (285.95)
$PMC \times Post$	-1952.68 (1578.78)	103.86 (1362.14)	-808.94 (2230.55)	-1767.76 (1244.63)	90.82 (1546.00)	360.12 (1348.26)	-437.34 (1861.11)
t	0.00 (0.02)	-0.02 (0.02)	-0.08*** (0.03)	0.00 (0.01)	-0.01 (0.02)	0.01 (0.01)	0.00 (0.02)
$t \times Post$	-0.01 (0.03)	0.01 (0.03)	0.06* (0.03)	0.01 (0.01)	0.00 (0.03)	-0.00 (0.02)	-0.03 (0.03)
$Post$	0.06 (0.07)	0.06 (0.07)	0.13 (0.08)	0.01 (0.03)	-0.02 (0.06)	0.00 (0.04)	0.13** (0.06)
R^2	0.86	0.84	0.79	0.65	0.83	0.32	0.82
N	1072.00	1072.00	1072.00	1072.00	1072.00	1072.00	1072.00
$Pre - Mean$	4.84	2.88	2.68	0.32	3.26	0.09	1.99
$Mean(PMC)$.000032			
$Mean(PMC PMC > 0)$.000047			

^a P-values from county clustered standard errors in parenthesis. The year 2008 is not included in the analysis as counties are identified starting in 2009. Counts deaths where the drug had a causal role as determined by Florida's Medical Examiners Commission.

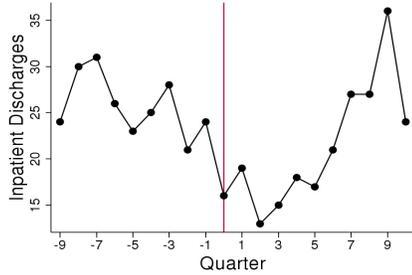
4.2.2 Hospital Discharges



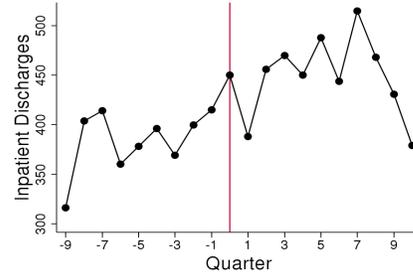
(a) Opioids



(b) Complements



(c) Heroin



(d) Cannabis

Figure 6: Inpatient Hospital Discharges in Florida (2008-2012)

Figure ?? plots inpatient hospital discharges for the abuse of drugs with a mention of opioids, heroin, benzodiazepines (e.g. complements) and cannabinoids. Unlike other outcomes, this data identifies drug class rather than active ingredient, making the decomposition of oxycodone and substitutes impossible. As heroin is identified from other opioids, results are reported separately. These figures resemble those in the previous section, suggesting that changes in the consumption of oxycodone and its complement alprazolam are driving overall changes in their respective drug class.

Table ?? reports cross-county estimates from Equation ?? for inpatient discharges and outpatient emergency department discharges. Panel A shows that during the

epidemic, inpatient hospitalizations with a mention of opioid increased in Florida, specifically in pill mill counties. After the intervention, inpatient hospitalizations declined for opioids and complements and increased for heroin, specifically in pill mill counties. Other drug classes are statistically insignificant. Similar results are found for outpatient emergency department discharges (See Panel B).

Table 4: Log Hospital Discharges (2008-2012)

	Opioids	Complements	Stimulants	Marijuana	Cocaine	Heroin
Panel A: Inpatient Hospital Discharges						
$PMC \times t$	493.79** (219.02)	260.94 (247.86)	551.78** (237.80)	227.84 (196.12)	-366.04* (209.83)	-130.09 (137.82)
$PMC \times t \times Post$	-1041.92*** (337.50)	-792.18** (364.01)	-382.70 (345.13)	-25.31 (324.70)	323.90 (258.34)	607.40*** (177.64)
$PMC \times Post$	-667.96 (1568.23)	432.67 (1552.28)	846.91 (1690.88)	-2103.56 (1597.32)	2360.49 (1853.82)	-2540.97 (1535.71)
R^2	0.95	0.95	0.79	0.91	0.93	0.68
N	1311	1311	1311	1311	1311	1311
$Mean$	45.20	33.40	2.13	11.42	17.97	0.43
Panel B: Outpatient Emergency Department Discharges						
$PMC \times t$	160.58 (192.95)	109.21 (217.33)	271.04 (193.80)	178.55 (241.74)	-543.03** (256.89)	-815.58*** (206.93)
$PMC \times t \times Post$	-571.92* (300.65)	-542.19 (330.24)	-6.51 (272.17)	49.18 (388.60)	495.36 (364.19)	1269.85*** (283.28)
$PMC \times Post$	547.63 (1592.47)	403.10 (1354.28)	-1177.42 (1377.64)	-2514.91* (1489.27)	651.75 (1829.08)	-800.26 (1456.58)
R^2	0.94	0.93	0.82	0.90	0.92	0.79
N	1304	1304	1304	1304	1304	1304
$Mean$	31.15	24.04	2.96	11.71	18.47	0.81
$Mean(PMC)$.000032					
$Mean(PMC PMC > 0)$.000047					

^a P-values from county clustered standard errors in parenthesis.

4.2.3 Substance Abuse Treatment

Table 5: Log Substance Abuse Treatment (2008-2012)

	Clients on Opioid Assisted Therapy	Total Clients	Total Admissions
<i>Florida</i> × <i>Post</i>	0.11*** (0.02)	-0.26*** (0.03)	-0.19*** (0.03)
<i>Post</i>	0.14*** (0.02)	0.14*** (0.03)	-0.06* (0.03)
R^2	0.20	0.19	0.15
N	11,019	11,019	11,019
<i>Mean</i>	220	869	3,116
% Δ	13.44	-26.02	-15.98

^a State clustered standard errors in parenthesis. Opioid assisted therapy includes methadone and buprenorphine clients. See Appendix (Figure ??) for graphical evidence on parallel trends. For % Δ use $100 \times (e^{((Post)+(Florida \times Post))} - e^{(Post)})$.

From previous sections, it is clear that Florida experienced a substantial decline in oxycodone supply. In response, users either switched to substitute drugs or ceased consumption. Because drugs are addictive, users often rely on substance abuse treatment to help cease consumption. This section examines the impact of supply-side interventions on substance abuse treatment admissions. Such analysis can help with the forecast of substance abuse treatment resources required after a supply-shock.

Table ?? reports results from Equation ?? using NSSATS data.⁴³ Totals are aggregated at the county level to capture any impact of the intervention on facility entry or exit. Columns (1) and (2) represent total clients who received methadone and buprenorphine for detoxification or maintenance purposes on March 30. Column (3) represents total clients who received substance abuse services in March and were still enrolled in treatment on March 30. Column (4) represents the approximate

⁴³See appendix for graphical evidence on parallel trends.

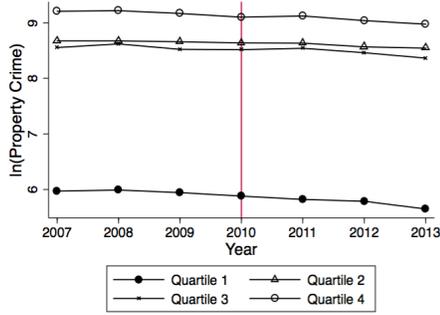
number substance abuse treatment admissions in the recent 12-month period.

During the post period, the overall number of clients receiving substance abuse services in Florida counties was declining. However, the average number of clients receiving opioid treatment increased by 13%. This suggests that some individuals sought to rehabilitate after the supply-shock. Nonetheless, this amount is small in absolute magnitude, suggesting that many individuals either quit without assistance or were directly treated by prescribing practitioners.

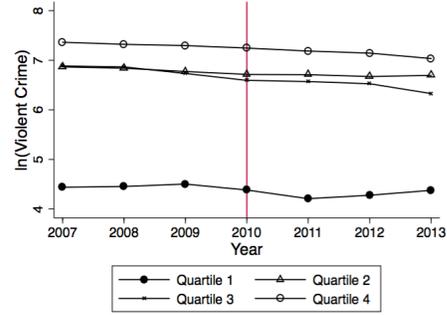
4.3 Crime, Punishment and Law Enforcement Resources

This section is interested in the effect of supply-side interventions on criminal activity, punishment and law enforcement resources. Table ?? reports cross-state and cross-county estimates from Equation ?. In Panel A, the treatment group is a dummy variable equal to one for Florida and zero for all other states.⁴⁴ In Panel B, the treatment group is continuous variable defined as the total number of pain clinics per capita in the county pre-intervention. Graphical evidence from Panel B regressions can be seen in Figure ??, which plots outcomes by pain clinic per capita quartiles. According to Table ?? estimates, there is no evidence that supply-side interventions had an effect on drug arrests. This is consistent with the conviction of a small number of big suppliers rather than that of a large number of small suppliers or individual consumers. This suggests small social costs of punishment from incarceration. As for index crimes, although Panel A displays statistically significant declines for both, violent and property crimes, Panel B suggests these declines were unrelated to the pill mill crackdown. These findings are consistent with survey data documenting a small prescription drug street market. Columns (4) and (5) display total controlled substances losses reported by suppliers to the DEA. Panel A reports that post-

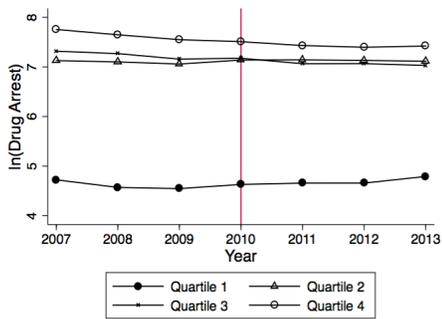
⁴⁴See appendix for graphical evidence on parallel trends.



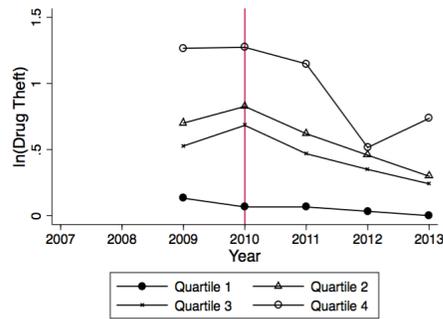
(a) Property Crime



(b) Violent Crime



(c) Drug Arrests



(d) Drug Theft or Loss

Figure 7: Log Crimes and Drug Arrests by Pain Clinics Per Capita (2007-2013)

Notes: Figures (a), (b) and (c) are constructed using data collected by the Florida Department of Law Enforcement. Figure (d) is constructed using data collected by the Drug Enforcement Administration. Outcomes are broken into pain clinics per capita quartiles. Pain clinic counts are proxied with licensure data collected by Florida’s Department of Health.

intervention, the average number of such reported losses, whether by armed robbery or night break-in, declined by -56.71% and -24.89%, respectively. Pill mill counties are driving these results. Note, however, that the magnitude of these losses is small.

Table 6: Index Crimes, Arrests, ans Drug Theft (2008-2012)

	Log Arrests		Log Index Crimes		Log Drug Theft or Loss	
	Drug Arrests	Property Crime	Violent Crime	Armed Robbery	Night Break-In	
Panel A: Nation Level Analysis						
$Post \times Florida$	-0.05 (0.09)	-0.07*** (0.01)	-0.13*** (0.02)	-0.79*** (0.09)	-0.33*** (0.09)	
$Post$	-0.09 (0.09)	-0.02** (0.01)	-0.04** (0.02)	0.03 (0.07)	-0.13 (0.08)	
R^2	0.95	1.00	1.00	0.89	0.89	
N	252.00	255.00	255.00	208	208	
$Mean$	149,267	713,326	113,925	63	50	
$\% \Delta$	-4.51	-6.68	-11.75	-56.71	-24.89	
Panel B: County Level Analysis						
$Post \times PMC$	-3813.42 (2531.04)	-742.05 (804.32)	180.79 (1478.77)	-4691.53*** (1702.68)	-5161.14** (2553.32)	
R^2	0.98	1.00	0.99	0.73	0.59	
N	335	332	334	268	268	
$Mean$	2228	10796	1707	0.95	0.75	
$Mean(PMC)$.000032			
$Mean(PMC PMC > 0)$.000047			

^a State clustered standard errors in parenthesis. Drug theft or loss data are only available starting on 2009. For $\% \Delta$ use $100 \times (e^{(Post)+(Florida \times Post)} - e^{(Post)})$. See appendix for parallel trends assumption in Panel A.

4.4 Intensive vs. Extensive Margin

The previous section showed that on the net, supply-side interventions resulted in a substantial negative shock to oxycodone quantities, while other prescription drugs displayed modest changes. Next, total suppliers and total supply by healthcare provider type are examined. This analysis shows whether supply reductions are explained by changes in the intensive or extensive margin, and identifies margins of adjustment that might have offset or reinforced the intended effects of supply-side interventions. Although the general equilibrium effects were consistent with the intended partial equilibrium effects, decomposing the mechanisms by which these results are attained can aid in future drug policy design.

In 2009, a year before the intervention, dispensing practitioners, pharmacies and hospitals in Florida accounted for 11%, 87% and 2% of total oxycodone supply, respectively. For the average state, the breakdown was 0.15%, 95% and 5%, respectively. Compared with other states, Florida practitioners dispensed a much larger share of total oxycodone grams. Moreover, Florida practitioners dispensed 94% of total oxycodone grams dispensed by all practitioners in the entire nation. By 2013, three years after the crackdown, dispensing practitioners, pharmacies and hospitals in Florida accounted for 0.1%, 95.4% and 4.5% of total oxycodone supply, a breakdown resembling that in the rest of the nation.

Figure ?? plots oxycodone grams purchased by dispensing practitioners and pharmacies, and Figure ?? plots the number of dispensing practitioners and pharmacies purchasing oxycodone grams. Subfigures ?? and ?? show that post intervention, both outcomes declined abruptly for dispensing practitioners. This suggests the extensive margin, that is, number of suppliers, played an important role in the formation and dissolution of the epidemic in the case of dispensing practitioners. Other

drug groups, including stimulants, display similar patterns. These results are consistent with the effective implementation of tighter dispensing practitioner laws. They are also consistent with a shock to distributors. Note that a sharp decline in the number of dispensing practitioners does not translate into a sharp decline in the number of practitioners operating in Florida. Practitioners could still prescribe and administer drugs as long as their medical licenses/ DEA registrations remained active.

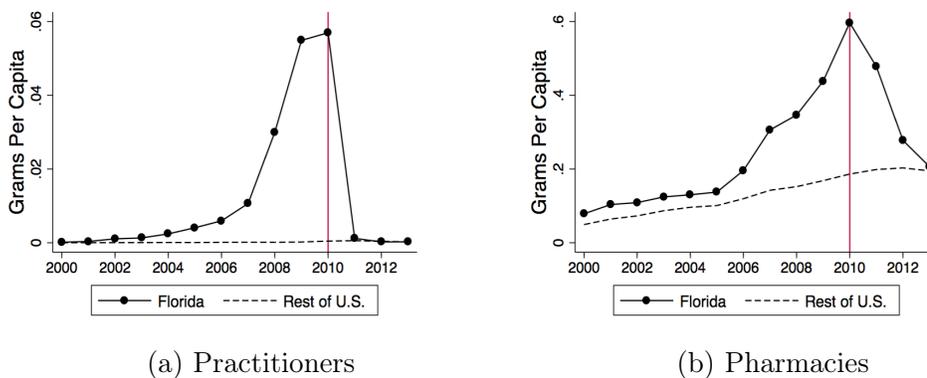


Figure 8: Oxycodone Supply (2000-2013)

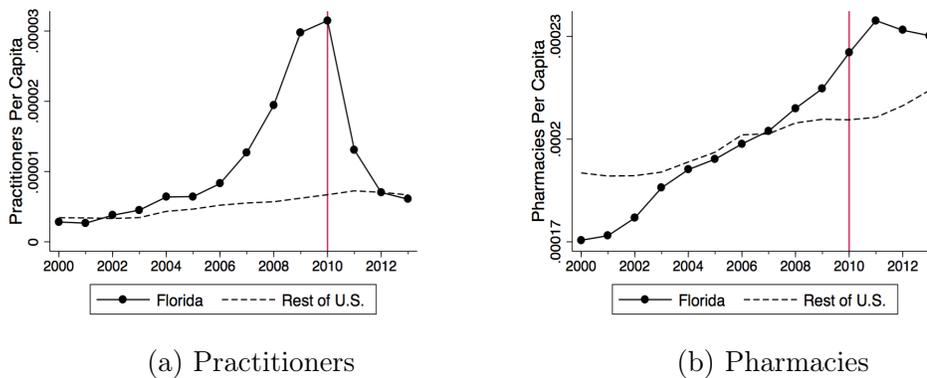
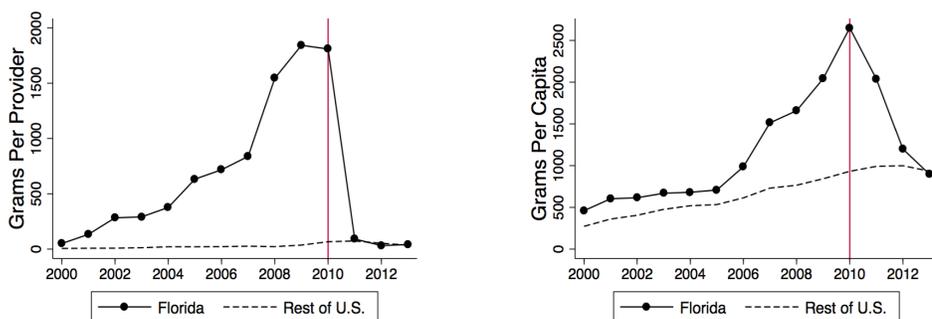


Figure 9: Oxycodone Suppliers (2000-2013)

As for pharmacies, subfigure ?? shows an abrupt trend break in supply, while



(a) Practitioners (b) Pharmacies

Figure 10: Oxycodone Supply Per Supplier (2000-2013)

subfigure ?? shows that supplier size continued to increase over the following year but then stabilized. This suggests the extensive margin played less of a role in the case of dispensing pharmacies. Various components of the intervention could explain these results for pharmacies. First, the DEA revoked the registration of a number of pharmacies filling prescriptions from pain clinic doctors, including chain pharmacies such as CVS and Walgreens. This action could have affected supply not only by incapacitating these pharmacies, but also by deterring other pharmacies from oversupplying oxycodone. A second story could be a shock to distributors. Finally, findings might be explained by the effect of supply-side interventions on physicians operating from pain clinics. Specifically, since pharmacies cannot dispense prescription drugs to patients without a physician’s prescription, a shock to oxycodone supply might be explained by incapacitated or deterred physicians.⁴⁵ The massive pain clinic shutdown (see Figure ??) suggests this third explanation might be most important. Considering the market share of dispensing practitioners was small relative to total supply, it is possible that enforcement rather than regulation had a larger role to play in the total negative shock to oxycodone supply.

⁴⁵There are some exceptions in emergency cases.

To examine the intensive margin, Figure ?? plots total oxycodone grams per supplier in Florida and the U.S. by practitioners and pharmacies. In 2009, the average doctor dispensed as much oxycodone as the average pharmacy. Post intervention, supply intensity declined sharply for practitioners and steadily for pharmacies. These graphs show that not only total suppliers contributed to overall changes in oxycodone supply, but that the amount supplied by suppliers also mattered.

4.5 Alternative Explanation

Another intervention implemented during this period was Florida's Prescription Drug Monitoring Program (PDMP), an electronic database that tracks substances dispensed in the state.⁴⁶ The information collected is available to registered healthcare providers to help guide their decisions when prescribing and dispensing controlled substances. PDMPs aim to address the problem of asymmetric information that occurs when healthcare providers cannot differentiate medical from non-medical users. In Florida, the PDMP became operational in September 2011 and practitioners began accessing the data on October 2011.

Although the PDMP's influence cannot be ruled out, it is unlikely a driving factor of Florida's drastic shock to oxycodone quantities for a variety of reasons. First, it was implemented and became accessible well over a year after oxycodone's sharp trend break in mid-2010. Second, the 2011-2012 PDMP Annual Report suggests that within a year of implementation, the database was not being used substantially. From October 2011 to September 2012, the PDMP received 2.4 million queries by registered users, far below the 44.5 million prescription records reported to the PDMP. Third, since the PDMP affected controlled substances in schedules II-IV, one would expect

⁴⁶The data collected usually includes the names and contact information for the patient, prescriber, and dispenser; the name and dosage of the drug; the quantity supplied, the number of authorized refills; and the method of payment.

similarly large reductions in other controlled substances within these schedules. In this analysis no such evidence is found. Fourth, previous PDMP studies report small or no impact of implementation on supply (Brady et al., 2014, Paulozzi et al., 2011). In fact, a study examining the impact of the PDMP in Florida near the date of implementation only finds slight declines in opioid prescribing and use (Rutkow et al, 2015).⁴⁷ This is not surprising as opioid supply in Florida had been declining for over a year and a half prior to PDMP implementation. Fifth, this paper shows strong evidence across multiple datasets that pill mill counties are driving the results, which is consistent with the massive pill mill shutdown, which resulted in a 59% decline in pain clinic licenses in the state. Finally, it is unlikely that the fact Florida doctors dispensed 94% of total oxycodone dispensed by all doctors in the nation was the result of asymmetric information.

5 Conclusions

The human and economic costs of supply-side interventions are substantial, with interdiction, international and domestic enforcement receiving \$15.1 billion or 59% of the federal drug control budget in 2011 (ONDCP, 2013). Yet, multiple empirical studies regarding the effectiveness of supply-side interventions in the market for illegal drugs fail to find evidence that marginal increases in enforcement sustainably and substantially raise prices and reduce consumption.

This study suggests that in the context of prescription drugs, supply-side interventions can be an effective tool against drug abuse. The pain clinic crackdown in Florida reduced oxycodone supply and increased street prices substantially and sustainably. There is no evidence of significant supply spillovers across states, healthcare

⁴⁷Note that these findings will be confounded with the pill mill crackdown in Florida which began prior to PDMP implementation.

providers or other opioid pain relievers. Reductions in supply translated to reductions in measures of opioid pain reliever consumption, including hospitalizations and deaths. Substitution to heroin, an illegal drug opioid, is found. This offsetting effect, however, is small relative to substantial public health gains from decreases in oxycodone supply and consumption. There is no evidence of increases in crime or drug arrests.

The success of the intervention might be due to the greater transparency, regulation and technological entry costs characteristic of the production and distribution process of pharmaceuticals. Results from this study suggest that targeting pharmaceutical's legal suppliers can be an effective policy tool in the war against prescription drug abuse, especially in the face of an epidemic.

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A Equianalgesic Opioid Dosing

Equianalgesic opioid dosing is drawn from McPherson (2009). Table ?? depicts milligram equivalence that allows to convert doses across opioids. Note that a highly potent drug does not necessarily translate into a preferred drug among non-medical users, as side effects and euphorogenic properties can vary. For the purpose of this study, grams are converted assuming oral doses when possible, and transdermal doses when not. NTP and substitute grams are converted into oxycodone potency units.

Table 7: Equianalgesic Opioid Dosing

Drug	Route	Mg	Drug	Route	Mg
Oxycodone	Oral	20	Methadone (30-90mg OM)	Oral	7.5
Fentanyl	Transdermal	0.36	Methadone (90-300mg OM)	Oral	5
Oxymorphone	Oral	10	Methadone (>300mg OM)	Oral	3.75
Oxymorphone	Intravenous	1	Hydrocodone	Oral	30
Morphine	Oral	30	Hydromorphone	Oral	7.5
Morphine	Intravenous	10	Hydromorphone	Intravenous	1.5
Codeine	Oral	200	Meperidine	Oral	300
Codeine	Intravenous	100	Meperidine	Intravenous	100
Tramadol	Oral	120	Tramadol	Intravenous	100
Buprenorphine	Sublingual	0.4	Buprenorphine	Intravenous	0.3
Buprenorphine	Transdermal	0.43	Fentanyl	Intravenous	0.1

B Drug Group

Table 8: Drug Group by Controlled Substance

Drug Group	Controlled Substance	Comments
Oxycodone	Oxycodone	Schedule II
Prescription Substitutes	Hydrocodone	Other opioid pain relievers not used in medication-assisted treatment of opioid addiction.
	Morphine	
	Oxymorphone	
	Hydromorphone	
	Fentanyl	
	Codeine	
Illegal Substitutes	Meperidine	
	Heroin	Opioid drug.
Other Illegal Drugs	Cocaine	
	Marijuana	
NTPs		
Prescription Complements	Methadone	Opioid drugs used in medication-assisted treatment of opioid addiction (SAMHSA, 2011).
	Buprenorphine	
Prescription Stimulants	Alprazolam	Benzodiazepine drug. Schedule IV. (Jones et al., 2012)
	Amphetamines	Schedule II

C Additional Graphical Evidence

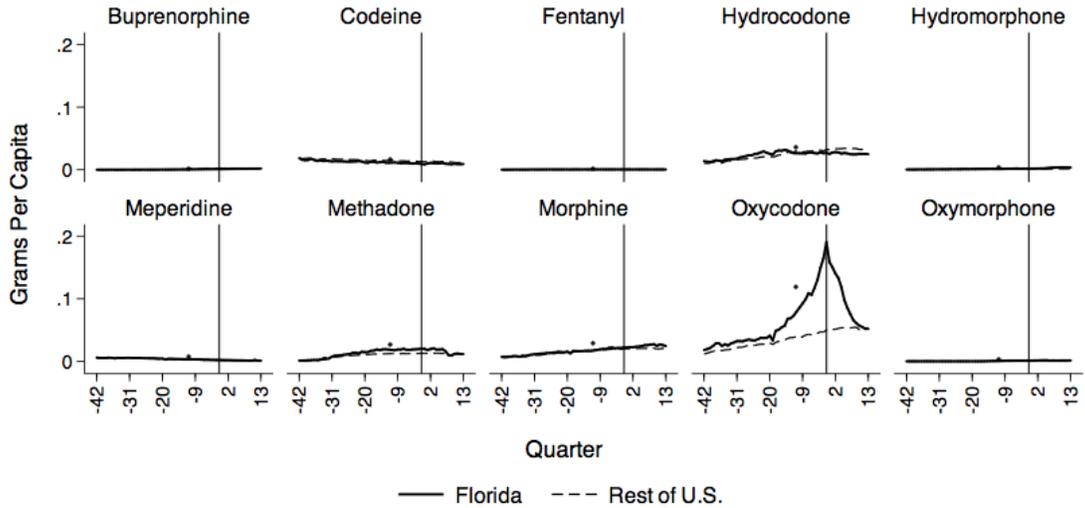
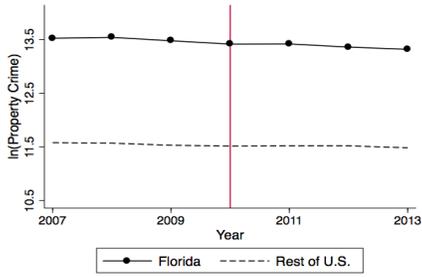
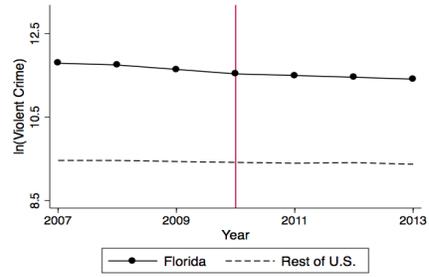


Figure 11: Quarterly Opioid Supply Per Capita by Active Ingredient (2000-2013)

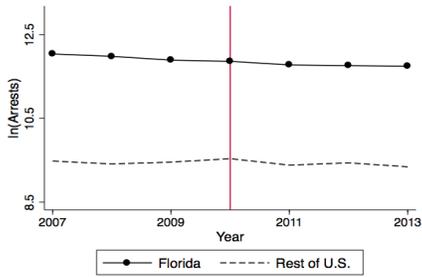
Notes: Figure is constructed using ARCOS Report 2 data. Total grams are in units of the active ingredient and are divided by 2010 population estimates. Morphine, fentanyl and hydromorphone grams are not reported in 2012. See data section for procedure on imputed values. See Figure ?? for potency adjusted grams.



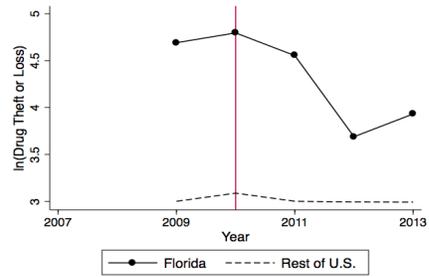
(a) Property Crime



(b) Violent Crime



(c) Drug Arrests



(d) Drug Theft or Loss

Figure 12: Log Crimes and Drug Arrests

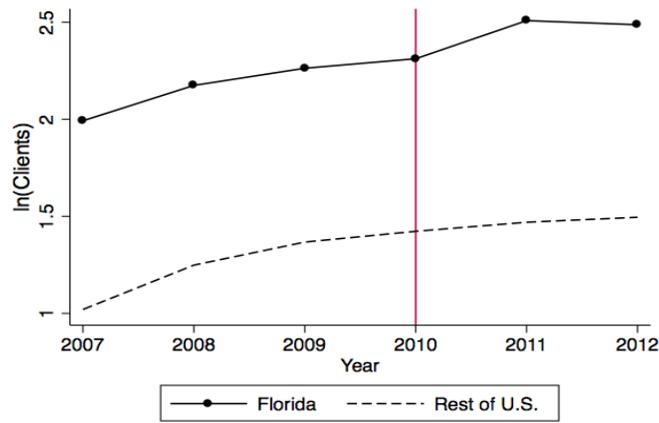


Figure 13: Log Methadone or Buprenorphine Clients (2007-2012)

Notes: Figure is constructed using NSSATS data.