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Are supply-side drug control efforts effective? Evaluating OTC regulations targeting methamphetamine precursors[☆]

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ABSTRACT

Enforcement efforts are the primary approach to reduce illegal drug use in the U.S., but evidence on their effectiveness is mixed. We provide new evidence on the effectiveness of enforcement efforts by using rich administrative records and the staggered implementation of state laws targeting over-the-counter medicines that can be used to produce methamphetamine. We estimate that the regulations reduced the number of methamphetamine laboratories operating in a state by 36%. We find no evidence of changes in methamphetamine consumption or arrests for drug possession, suggesting people were able to find methamphetamine produced elsewhere. Though we find evidence suggesting methamphetamine producers responded to regulation by obtaining precursors from neighboring states that lacked laws, they do not appear to have systematically moved production to neighboring states. This suggests that production shifted over national borders.

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1. Introduction

Current estimates indicate that the cost of drug abuse in the U.S. exceeds $200 billion annually (ONDCP, 2004).[1] Government efforts to reduce these costs fall into three categories: prevention, treatment, and enforcement. In fiscal year 2010, approximately $1.5 billion, $3.7 billion, and $9.8 billion were allocated to these three areas, respectively (ONDCP, 2010). Despite the fact that enforcement efforts are the primary approach to reduce drug use in the U.S., there is little consensus on their effectiveness. Some studies find no impact of enforcement on prices (DiNardo, 1993), others a negative relationship (Yuan and Caulkins, 1998), and still others a positive relationship (Miron, 2003). This is likely due to the difficulty in finding credible research designs.

The evidence is more compelling for large enforcement efforts. Recent studies examining abrupt, plausibly exogenous changes in enforcement efforts provide evidence that enforcement can reduce illegal drug use. A number of authors have documented that the reduction in heroin availability in Australia resulting from the Taliban eradicating poppy production at least temporarily reduced use (Weatherburn et al., 2002). Others have provided compelling evidence that the massive reduction in methamphetamine availability in the mid-1990s substantially (though temporarily) reduced drug related harms (Cunningham and Liu, 2003); (Dobkin and Nicosia, 2009); (Cunningham and Finlay, 2013). This finding is perhaps not surprising given that this reduction in drug availability is likely the largest and most abrupt in any developed country in the past 40 years.

Estimates of the effects of large enforcement efforts may be of little use in predicting the effects of typical enforcement efforts. The reason is that most enforcement efforts likely only moderately reduce availability of the targeted drug. If modest reductions disproportionately impact the least addicted and criminally-involved users, then projections from these two large enforcement efforts may be invalid. An additional concern about using the estimates from these interventions is that they are identified largely from time-series variation and thus provide limited insight into the persistence of the effects of enforcement efforts, given that it is likely that other unrelated changes in illicit drug markets occurred subsequently.

The objective of this study is to provide credible estimates of the impact of a smaller, but more typical enforcement effort than the ones examined in Cunningham and Liu (2003); Dobkin and Nicosia (2009);

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[1] The majority of these costs are due to lost productivity (71%) with the remainder due to spending on the criminal justice system (20%) and health care (9%). A significant portion of the lost productivity is due to criminal activity as people who are incarcerated or pursuing criminal careers are typically not contributing significantly to the economy.

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Weatherburn et al. (2002). Specifically, we evaluate the impact of state restrictions on the sales of retail cold medicines that can be used to produce methamphetamine on the production and consumption of methamphetamine. Between 2004 and 2006, 35 states enacted laws regulating the sale of over-the-counter (OTC) cold medicines that contain pseudoephedrine or ephedrine, a key input in methamphetamine production.[2] These restrictions limited the amount of the products consumers could purchase, required consumers to show identification upon purchase, and forced retailers to keep a logbook of purchasers and place the products in a secure location. An evaluation of the effectiveness of these laws is important because they placed a burden on manufacturers, retailers, and legitimate consumers of cold medicines and because further restrictions have been passed or proposed in some states to make these products available only by prescription.

Two key features of the precursor regulations help us estimate their effect on illegal drug production and consumption. First, both the time period and geographic area affected by the laws are known and well-defined. Second, there is variation in when states enacted the laws. We exploit this variation to estimate the effects of the laws using newly-collected data on their enactment dates along with administrative datasets collected in the course of law enforcement, the provision of health services, and the establishment of workplace safety. One of our measures of methamphetamine production is drawn from the National Clandestine Lab Seizure System (NCLSS). These data contain the location, discovery date, and production capacity of methamphetamine laboratories that were seized or discovered by law enforcement officials.[3] Our other measures relating to production are the price and purity of methamphetamine purchased by law enforcement officials. These measures are constructed from transactions in the Drug Enforcement Agency's System to Retrieve Information from Drug Evidence (STRIDE). We also employ proxies for consumption based on employee drug testing from Quest Diagnostics and from hospital inpatient drug testing from the Health Care Utilization Project's Nationwide Inpatient Sample and State Inpatient Datasets.[4] Although these data are specific to particular populations, they are strongly correlated with survey estimates of methamphetamine use in the general population. Finally, we examine drug-related arrests using the FBI's Uniform Crime Reports. Each dataset is sufficiently rich that we can estimate rates for each state on a monthly basis. Monthly estimates at the state level make it possible to take full advantage of the geographic and temporal variation in the implementation of these laws.

We examine the effect of the laws using a difference-in-difference model where the treatment is at the state level, with controls for state and month/year fixed effects and state-specific time trends. In this model, identification requires that there are no state-level non-linear trends that are correlated with methamphetamine production and consumption and the introduction of the OTC restrictions. Our results are robust to adding controls for possible confounders. Event studies support the validity of our main conclusions and provide insight into the dynamic effects of the OTC restrictions.

The OTC restrictions significantly decreased within-state methamphetamine production. We estimate that the laws caused a 36% reduction in the number of methamphetamine laboratories. The reduction was largest among the laboratories with the smallest production capacities, but we find evidence of reductions in the number of larger laboratories as well. We estimate a decline in overall domestic production of methamphetamine of about 25%. However, despite the disruption of domestic methamphetamine production, we find no evidence of a change in the quality-adjusted price, consumption, or drug related arrests. Our result that the laws reduced the number of domestic methamphetamine laboratories but left consumption unchanged suggests that people were able to obtain methamphetamine produced outside of their state of residence.

If there is interstate movement of OTC precursors or methamphetamine, regression models that assume that methamphetamine production or consumption in a state does not depend upon the regulatory status of neighboring states will understate the effect of a national policy. We assess the severity of this issue and adjust for it by estimating regressions that allow for displacement to neighboring states. This approach is most cleanly implemented in the analysis of the number of labs, because these records are available at the county level. The results from this analysis suggest that some producers operating near state borders were able to circumvent the laws by importing precursors from a neighboring state without a law. However, we did not find any evidence that production shifted across state borders in response to the laws, possibly due to the cost of acquiring a location for methamphetamine production.[5] The decrease in the number of labs in a state after a law is implemented along with the finding that consumption was not significantly affected by the law suggests production moved outside the United States. This is consistent with evidence from the Drug Enforcement Agency that methamphetamine imports from Mexico increased around the time the laws were enacted. This suggests that though the fully implemented law in the United States did reduce domestic production it did not substantially reduce consumption of methamphetamine.

The remainder of the paper is organized as follows. Section 2 provides background on methamphetamine and the efforts to reduce its availability. The administrative data sources used in this study are described in Section 3. In Section 4, we describe our empirical strategy. Section 5 presents our findings with respect to production, consumption and arrests, discusses robustness, and presents the estimates that correct for displacement. Finally, we conclude.

2. Background on methamphetamine and precursor legislation

Methamphetamine is a central nervous system stimulant that induces a state of pleasure, high energy, and alertness that lasts up to 12 hours. For some, methamphetamine use and withdrawal are associated with adverse physical and psychological events including cardiovascular complications, premature mortality, mood disorders, cognitive impairment, risk-taking and aggressive behaviors (NIDA, 2002; Rawson et al., 2001; Simon et al., 2001; Lynch et al., 2003; ONDCP, 2006; SAMHSA, 2008). In 2005, methamphetamine use was associated with nearly 1000 deaths in the U.S. and more than 169,000 individuals sought treatment for methamphetamine or amphetamine

[2] States that did not implement their own legislation or implemented weak legislation became subject to the Combat Methamphetamine Enforcement Act (CMEA) of 2006.

[3] McBride et al. (2011) used three years of the NCLSS data (2004–2006) to study the effect of the OTC sales restrictions on methamphetamine labs only among states that adopted the regulations before October 1, 2005. The focus of their study was to measure the effects of different aspects of the laws (e.g. restrictions on quantity versus product placement) on methamphetamine labs only, while our goal is to more comprehensively assess the effects of the restrictions not only on production, but also on consumption and arrests. Our study also has three important strengths. First, our study includes every state and a longer pre- and post-period from January 2002 through March 2008. The longer post-period allows us to estimate any delayed responses to the laws, while a longer pre-period allows us to provide stronger evidence on the validity of our research design. Second, we include all states rather than only those who adopted early. And third, our models control for year/month dummies and state trends, while McBride et al. control only for year dummies. The more flexible controls mitigate the risk of misattributing the effect of other changes in drug markets to the OTC regulations.

[4] When an admission record includes a mention of amphetamine use it is typically the result of a positive drug test but in some cases may be solely due to the patient's report of their own drug use.

[5] Due to data limitations it is not possible to implement a county level analysis for the other outcomes. In a state level analysis that allows for spillovers we find no robust evidence of displacement. However, these estimates are imprecise due in part to inherent problems with modeling spillovers at the state level.

addiction.[6] Some researchers and law enforcement agencies have suggested that methamphetamine use causes property and violent crime (e.g., see Lynch et al., 2003).

Manufacturing methamphetamine is a relatively simple, but potentially hazardous process. Unlike most illicit substances, methamphetamine is a synthetic product whose critical precursors, ephedrine or pseudoephedrine, require a complex large scale industrial process to manufacture. Because of concentration in the production of ephedrine and pseudoephedrine, legislation aimed at reducing their diversion to methamphetamine production has the potential to reduce methamphetamine availability. In the last 25 years, the federal government passed several laws intended to do just that. The first was the Chemical Diversion and Trafficking Act of 1988, which regulated ephedrine and pseudoephedrine in bulk powder form, but left processed forms unregulated.[7] Next, the Domestic Chemical Diversion Control Act of 1993 placed restrictions on OTC ephedrine products (e.g. tablets) and increased DEA oversight of suppliers. Then, the Methamphetamine Control Act of 1996 tightened regulations on the sale of products containing methamphetamine precursors over 24 grams, but contained an exception for "blister packs".[8] Shortly thereafter, the Methamphetamine Anti-Proliferation Act of 2000 lowered the thresholds from 25 to 9 grams, but blister packs remained exempt. In response to each of the federal efforts methamphetamine producers switched to sources of precursors that remained unregulated. Among their innovations was exploiting OTC consumer medicines containing pseudoephedrine (CRS, 2007). Because of this, starting in 2004, individual states instituted controls on OTC cold and sinus medications such as Sudafed and Tylenol Cold to prevent their diversion to the production of methamphetamine. Federal legislation followed in the Combat Methamphetamine Act of 2005, which became effective in 2006.

The state and federal restrictions on OTC medicines containing methamphetamine precursors are the focus of our study. As shown in Table 1 of Appendix A, thirty-five states passed laws restricting the sales of OTC medicines beginning in January 2004. Then, all jurisdictions became subject to federal legislation regulating the sale of OTC medicines, which became effective in April and September 2006.

The most common state restrictions involved sales limits and product placement. Thirty-five states imposed purchasing quotas and required that the products be placed in secure locations. The majority of states also required that purchasers present identification and twenty-four states required that retailers maintain a logbook in order to prevent people from subverting the laws by making repeated purchases. We recorded the date when each of these four restrictions went into effect in each state.[9] The federal Combat Methamphetamine Act imposed sales restrictions in April of 2006 and as of September 2006 required purchasers to present identification and required retailers to keep products in a secure location and maintain a logbook. Table 1 of Appendix A presents the correlation between these various laws within a state and month which reveals that they are highly correlated.

Fig. 1 shows the time series of implementation for the four most common components of the laws. Purchase limits were typically an early component and were often bundled with restrictions intended either to deter theft or prevent people from circumventing quotas by making repeated purchases. Our analysis focuses on the timing of the earliest component — that is, the date at which each state first implemented any of the four restrictions described above. Similarly, we code the effective date of the federal law as April of 2006.[10]

3. Data

Because of the rapid rate of implementation across states, this study uses high-frequency administrative data sources to document the effects of the precursor regulations. We collected data on the number of methamphetamine labs, the price and purity of methamphetamine, positive drug tests for amphetamine among workers and hospital inpatients, and drug-related arrests. While some of these datasets were collected by state and federal agencies at the individual- or transaction-level, we use them to construct monthly measures for each state.

We have three measures that allow us to examine the impact of these regulations on drug production: the number of labs identified by law enforcement, methamphetamine purity, and the nominal price of methamphetamine. The National Clandestine Lab Seizure System (NCLSS) contains information on labs seized or discovered by law enforcement.[11] This dataset contains estimates of each site's production capacity, which is a critical measure in determining whether OTC regulations disproportionately impacted smaller labs. We rely on the Drug Enforcement Agency's System to Retrieve Information from Drug Evidence (STRIDE) to estimate the nominal prices and purity of methamphetamine.[12,13] These data record the date, location, method of acquisition (e.g., seizure, purchase, etc.), purity of the drug as determined by DEA labs, and, in the case of purchases, the price. We construct our price and purity measures using only observations on purchases (e.g., excluding seizures) in order to generate price and purity estimates from a consistent sample.[14]

We measure methamphetamine consumption using drug testing data from Quest Diagnostics and the Health Care Utilization Project (HCUP). Quest Diagnostics is the largest provider of workplace drug tests. Unfortunately, we only have data on positive drug tests among employees from January 2000 until April 2006 and so we are unable to follow states that adopted late for a full year.[15,16] For a longer perspective on a larger sample of individuals, HCUP provides information on hospital admissions. These data allow us to identify hospital admissions (for any cause) that tested positive for amphetamine. We rely

6 Death counts are derived from CDC tabulations of the Multiple Cause of Death file provided to the authors and are likely substantially biased downwards due to miscoding. Based on the Treatment Episode Dataset, methamphetamine accounts for the vast majority of drug treatment admissions for psychostimulants. See www.oas.samhsa.gov/2k8/methamphetamineTX/meth.pdf (Last accessed December 18, 2012).

7 Other inputs were also regulated by these and other regulations, but we focus here on the history of ephedrine and pseudoephedrine regulations as they are most relevant for this study.

8 The act also imposed monthly reporting requirements for "mail order" firms dealing in precursor chemicals.

9 We compared summaries of state legislation from the National Association of Chain Drug Stores, Office of National Drug Control Policy and National District Attorney's Association with the text of legislation from the 50 states and the District of Columbia. We resolved any inconsistencies by examining the text of the laws. In a few cases a Board of Pharmacy rule or executive order preceded the state and federal legislation.

10 The enactment dates for the state laws are included in Table 2 of Appendix B.

11 A lab seizure is defined as "an illicit operation consisting of a sufficient combination of apparatus and chemicals that either has been or could be used in the manufacture or synthesis of controlled substances." The NCLSS also records 1) "seizure of only chemicals, glassware, and/or equipment normally associated with the manufacturing of a controlled/illicit substance" and 2) locations "where discarded laboratory equipment, empty chemical containers, waste by-products, pseudoephedrine containers, etc., were abandoned/dumped." See: http://www.michigan.gov/documents/EPIC143InstrNew_131649_7.doc (last accessed December 29, 2012.)

12 We have records from STRIDE and NCLSS for the period from January 2000 to March 2008.

13 The STRIDE data have been criticized (Horowitz, 2001), but remain the best source of information on the purity and price of methamphetamine in the U.S.

14 We do this because there is no price information for observations on seizures.

15 These data were drawn from the ONDCP (2006) publication entitled "Pushing Back Against Meth". We attempted to obtain additional state-level data directly from Quest Diagnostics to extend our analysis period, but were unsuccessful.

16 Wozniak (2012) shows that the share of establishments using drug tests increased dramatically from 3.2% to 48.4% from 1988 to 1993, well before our sample period. However, the average rate between 1996 and 2007 was 46%, suggesting the share of workplaces using drug tests stabilized before our sample period. In the same paper, it is shown that Louisiana adopted legislation that provided incentives for workplace drug tests during our sample period. While Montana, Rhode Island, and Vermont adopted anti-testing legislation between 2002 and 2009, there is only mixed evidence that anti-testing legislation curbed workplace drug testing and these states comprise a small share of the U.S. population.

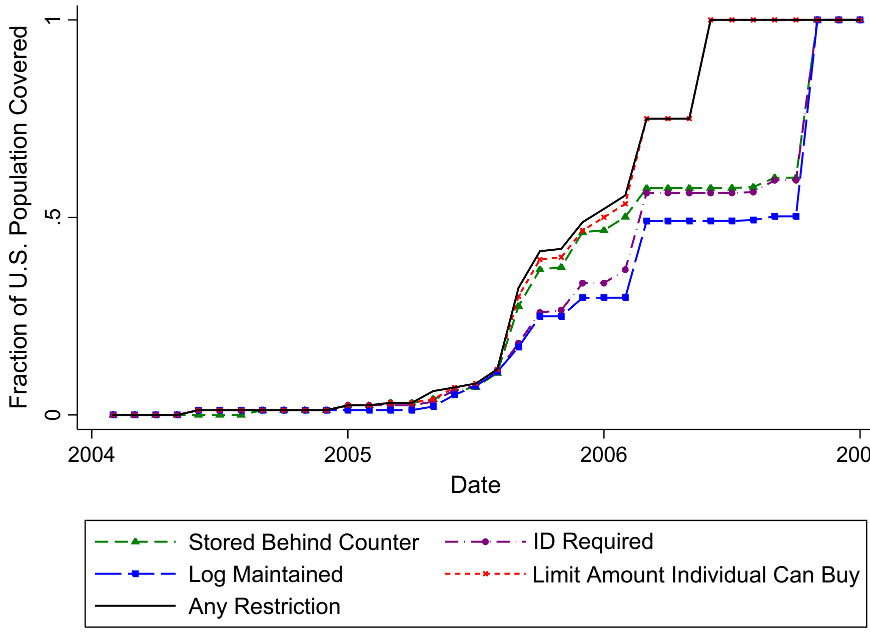

Fig. 1. Time series of laws restricting access to OTC medicines that can be used as methamphetamine precursors. Notes: population weights are derived from the census. The size of the limit on daily purchases varies from state to state, but in most state laws it is 3.6 grams per day and 9 grams per 30 day period. In a few states the 30 day limit is 7.5 grams.

primarily on HCUP's Nationwide Inpatient Sample (NIS), which is a sample of hospital admissions for up to 37 participating states from January 2000 to December 2007.[17] To increase precision, we supplemented the NIS data with the State Inpatient Dataset for January 2000 through December 2007 for the states of Arizona, New Jersey, Washington, and Iowa.[18]

To examine the link between the OTC regulations and drug related arrests we use the Uniform Crime Reports (UCR). We generate arrest rates for the possession and sale of illegal drugs for each state and month from January 2000 to December 2007. The UCR is based on reports to the FBI by individual police agencies. While monthly reports are requested, many agencies do not comply as reporting is voluntary. We drop observations from Alabama and Illinois because agencies in these states did not report on a monthly frequency.[19,20]

4. Empirical strategy

Our empirical strategy exploits the variation in the timing of states' implementation of OTC regulations documented in Fig. 1. We provide both graphical and regression-based evidence on how these restrictions impacted production, consumption and arrests.

We begin with a descriptive graphical analysis by plotting the average of each measure of methamphetamine production, consumption, and drug-related arrests over the sample period. These figures show changes in average state methamphetamine production and consumption over the time period in our study. In each figure we plot the fraction of the U.S. population covered by any OTC sales restriction to document whether changes in outcomes occurred concurrently with enactment of the regulations.

We next implement a regression analysis. The regression analysis leverages variation in the timing of state OTC regulations to separately identify the effects of the regulations from common changes in outcomes across all states. For each outcome, the regressions are estimated using data beginning in January 2002. The end dates vary across data sources as described in Section 3 and in the notes to the tables. We fit the following equation to the data using OLS:

$$Y_{st} = \beta OTC_{st} + \alpha_s + \gamma_t + \epsilon_{st} \qquad (1)$$

where Y_{st} is the outcome in state s and time t. The variable of interest OTC_{st} is an indicator set to zero in the months prior to implementation of a state's regulation, one afterwards, and the fraction of the month a regulation was implemented in months a regulation was enacted.[21] We control for common changes to all states by including a fixed effect for month/year γ_t and we control for unobservable time-invariant differences across states by including state fixed effects, α_s. The coefficient of interest β measures the effect of the OTC regulation on the outcome. When the outcome Y_{st} is a state average, we weight the data to improve the efficiency of our estimates.[22] The exact weights we use vary by outcome so we discuss them in Section 3 and the footnotes of the relevant tables. Standard errors are clustered by state. We expand on Model 1 by progressively adding state-specific linear and quadratic trends and covariates that include the state unemployment rate, number of households receiving food stamps, average temperature and average precipitation.[23]

Our results from Model 1 are supported by event-study analysis. Our key identification assumption is that there are no unmeasured non-

[17] We cannot differentiate amphetamines from methamphetamines in the drug testing and hospital data, but we do know from the TEDS data that more than 90% of the amphetamine abused in the U.S. is methamphetamine.

[18] Data from Iowa were only available for January 2004 through December 2007.

[19] In several other states there were large spikes across all arrest categories typically in June and December. These increases are likely due to a share of agencies reporting twice a year instead of monthly. In these cases, we replaced the outlier with the value in the preceding month within that state. Details are available upon request.

[20] Summary statistics for each of our outcomes are presented in Table 3 of Appendix C.

[21] If a state law was enacted on the 15th of February of 2005 OTC_{st} would be coded as $\frac{28-14}{28} = .5$ during that time period for that state, for example. Given the strong correlation in the adoption of different components of the laws, we define the OTC variable based on the earliest effective date for the four major retailer and consumer restrictions.

[22] Unweighted regression estimates are included in Appendix L. The results are less precisely estimated, but similar to the results from regressions with weights.

[23] Previous research has shown that there is an effect of unemployment (Raphael and Winter-Ember, 2001) and weather on crime (Jacob et al., 2007).

linear state specific trends correlated with the enactment of the regulations. Event study analysis allow us to examine any "pre-trend" that would raise concerns about the identification and also allow us to determine exactly when the regulations had an impact and how persistent it might be. We implement the event study by estimating the following equation with OLS:

$$Y_{st} = \sum_{j=-12}^{24} \pi_j 1(\tau_{st} = j) + \alpha_s + \gamma_t + \delta_s * t + \epsilon_{st} \tag{2}$$

where τ_{st} measures the month relative to the introduction of an OTC regulation, defined so that $\tau_{st} = 0$ if state s enacted an OTC regulation at any point in month t. We include state-specific linear time trends to mitigate the risk of OTC regulation endogeneity. We then produce graphs by plotting the estimated π_j coefficients with respect to event time, where the coefficients are measured relative to the month before an OTC restriction was put into place ($\tau_{st} = -1$).[24] We present the implied pre-trend and its standard error in each of the event-study figures. These were calculated by regressing the coefficients on each of the 12 dummies corresponding to periods before a law was introduced on a linear trend in event time.[25,26,27]

5. Results

5.1. Methamphetamine production

The intent of the OTC regulations is to prevent diversion of OTC medicines to the production of methamphetamine. Restricting access to these precursors could affect the supply of methamphetamine in two ways. It could limit the number of producers with access to sufficient precursors to produce methamphetamine. Second, it could change the quality of available methamphetamine. Quality will fall to the extent that the restrictions force producers to dilute their product or turn to inferior precursors which would result in a less pure product. Alternatively, the quality of available methamphetamine could increase if the restrictions reshuffled production to higher quality producers.

The ideal data for measuring the effect of the laws on methamphetamine production would be a census of labs for each state spanning before and after the laws went into effect. These records do not exist, so as an alternative we use the number of labs discovered by law enforcement agents. The number of labs discovered each month is an unknown fraction of the total number of labs in operation that month. The detection probability depends upon the efforts of law enforcement agents, the likelihood a lab catches fire, reports from the public, and other factors. The relationship between the percentage change in the number of discovered labs and percentage change in the number of labs in operation is given by:

$$\frac{D_{post} - D_{pre}}{D_{pre}} = \frac{p_{post} - p_{pre}}{p_{post}} \left(1 + \frac{Labs_{post} - Labs_{pre}}{Labs_{pre}}\right) + \frac{Labs_{post} - Labs_{pre}}{Labs_{pre}} \tag{3}$$

where D is the number of labs detected, $Labs$ is the number of labs in operation, p is the probability of detection, and the subscripts denote whether the period under consideration is before or after the implementation of the OTC law. If there is no change in the detection probabilities ($p_{post} = p_{pre}$), then the percentage change in the number of labs discovered is an unbiased estimate of the percent change in the number of labs in operation. There is anecdotal evidence that the OTC laws may have slightly increased the probability that a given lab will be detected as some police departments found cause to visit residences of people whose names appeared repeatedly in OTC sales logbooks. If the detection probability increases due to the law ($p_{post} > p_{pre}$), then using the percentage change in the number of labs detected as an estimate of the change in number of labs understates the reduction in operating labs by $100 * \left(\frac{p_{post} - p_{pre}}{p_{pre}}\right) \times \left(1 + \frac{Labs_{post} - Labs_{pre}}{Labs_{pre}}\right)$ percentage points.[28]

In Fig. 2, we present the average number of labs discovered across all states for each month. The labs have been split into three groups based on their estimated capacity measured as the amount of methamphetamine that could be produced in a single production cycle. Two facts emerge from the figure. First, for each group, there was a decrease in the average number of labs discovered beginning in early 2004. Second, by 2007 the average number of labs discovered in a state was less than half of what it was before 2004 for each of the three groups of labs. The timing of the reduction makes it clear that not all of the declines in the number of labs from 2004 to 2007 were due to the OTC regulations, as it began before states enacted the sales restrictions. This motivates our regression approach, which exploits variation in the timing of adoption to estimate the impact of the laws.

Fig. 3 presents the event studies created by estimating Eq. (2). The dependent variable is the number of labs discovered in a state. The figures show the reduction in the number of labs was not entirely due to common reductions in labs discovered across all states. There is no evidence of a pre-trend for any of the outcomes during the twelve months preceding the enactment of an OTC regulation, raising confidence in the validity of our identification assumption.

The corresponding regressions are presented in Table 1. Column 1 presents our most parsimonious model corresponding to Eq. (1), the second column adds state-specific linear time trends and corresponds to the more flexible version of the model used to construct the event study in Fig. 3, the third column adds quadratic state-specific time trends, and the final column adds covariates. The findings from the event study are confirmed by the regressions. Across specifications, the laws led to a decline in discovered labs. Column 2 of the first panel indicates a decline in the total number of discovered labs of approximately 36 $(\frac{-5.05}{13.9})$ percent. The other three panels present the estimates of the decline broken out by lab capacity. The reduction was large for labs with capacity less than two ounces and labs with capacity between two and eight ounces at approximately 32 and 54%. For the largest labs the reduction was smaller at 22% and not significant at the .05 level.[29]

We use the estimates from Eq. (1) and the average number of labs before the restrictions was in place to estimate the effect of the regulations on a state's methamphetamine production capacity. This allows us to summarize the total reduction in domestic production capacity with one number. Our data contains information on the number of labs discovered by state and month for labs grouped in six different production capacity intervals: labs with capacity less than two ounces, between two and eight ounces, eight ounces and one pound, two pounds and nine pounds, ten pounds and nineteen pounds, and labs with capacity of at least twenty pounds. We estimate the total reduction in production

[24] This was done by subtracting our estimate of π_{-1} from each of the event period coefficients. Note that event effects prior to a year before enactment are set to zero. This normalization is necessary because in our data all states eventually adopted the law. A full set of event dummies would be collinear with state effects and calendar effects.

[25] The standard error of the slope estimate was calculated using the delta method.

[26] Confidence intervals for each event study are presented in Figs. 2–12 of Appendix E.

[27] Event study graphs that do not control for state-specific time trends are in Appendix I.

[28] To get a sense of the possible scale of the bias consider the case where the OTC laws reduce the number of labs in operation by 50% and increase the probability of detection by 10%. Using the change in the number of labs detected will lead to an estimate of 45% which underestimates the change in the number of labs active by 5 percentage points.

[29] Our results are qualitatively unchanged if the dependent variable is measured as $log(1 + NumberLabs)$. Our results are also unchanged if we explicitly model the number of labs as count data and estimate specification 1 using a Poisson model estimated by maximum likelihood. However, the optimization algorithm we used to maximize the Poisson model's likelihood function failed to converge once we included both linear and quadratic state-specific trends. These results are presented in Tables 4–7 of Appendix F. Table 1 of Appendix F shows that the marginal effects of the laws on the number of discovered labs implied by the Poisson regressions range between 35 and 37%. For reference, the analogous estimates in our base specification range between 36 and 48%.

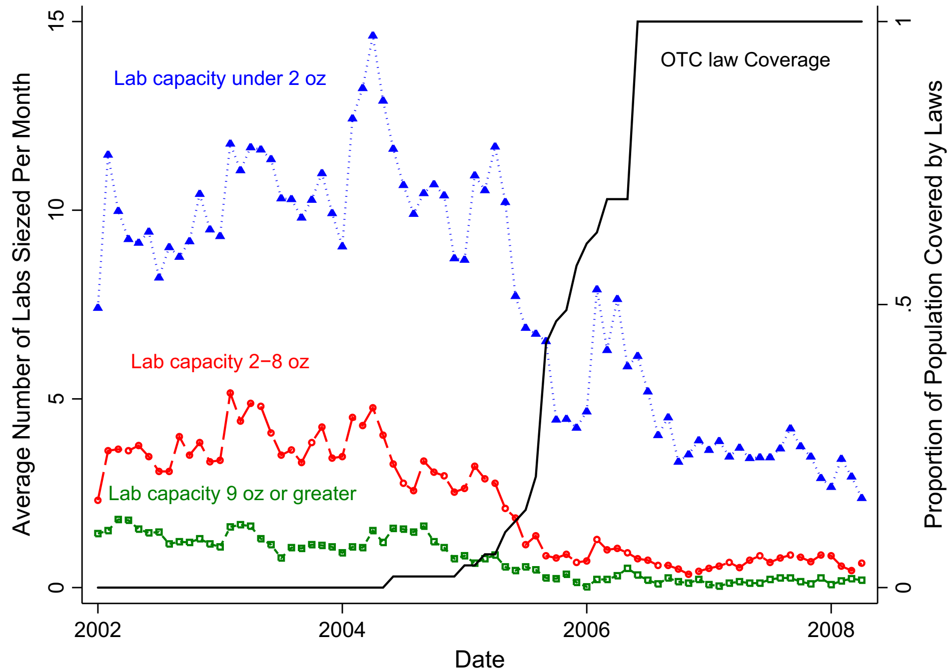

Fig. 2. Methamphetamine labs discovered or seized by capacity. Notes: the time series above are constructed using records from the National Clandestine Laboratory Seizure System. The figure contains the average number of labs discovered in a state by month.

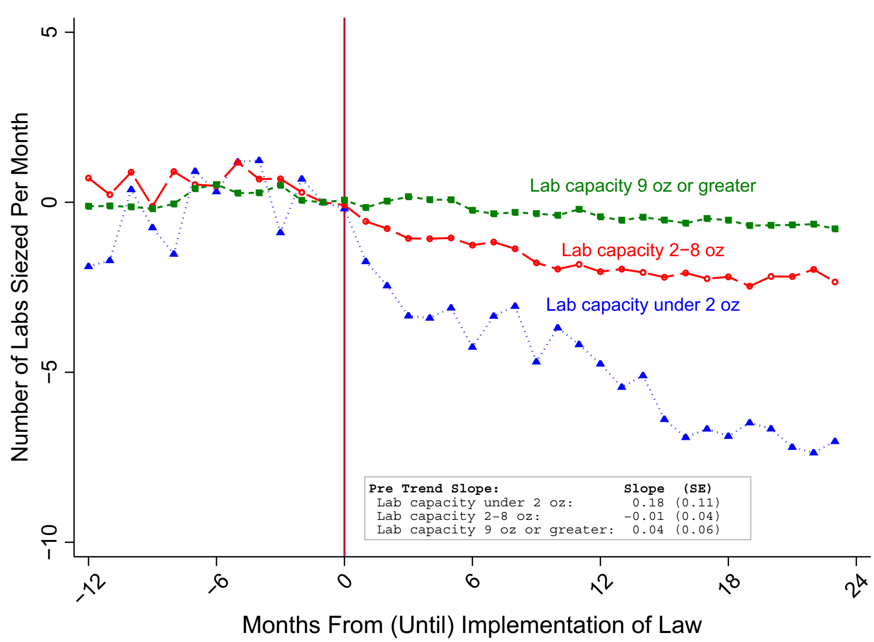

Fig. 3. Methamphetamine labs discovered or seized by capacity, event study. Notes: count of labs discovered was regressed on state fixed effects, year/month fixed effects, linear state time trends, and indicators corresponding to the number of months since any over the counter restriction went into effect. The graph contains OLS estimates of the coefficients on the indicators corresponding to the number of months since any over the counter restriction went into effect. The coefficients were normalized so the effect on the event dummy equal to one if a state enacted any OTC restriction in the next month is zero. The estimates include records for all 50 states and the District of Columbia from January 2002 through March 2008.

capacity by first expanding on the results presented in Table 1 by estimating the reduction in the number of labs for all six lab size groups.[30] The change in detected lab capacity is calculated by assigning the midpoint of the capacity range for each group and then taking the weighted average of the decreases in capacity. Our estimate of the percent reduction in productive capacity is given by the following expression:

$$PercentCapacityReduction = \frac{\sum_{j=1}^{6} \beta_j * Capacity_j}{\sum_{j=1}^{6} E\left[DiscoveredLabs|PreOTC, Capacity_j\right] * Capacity_j} \quad (4)$$

[30] The results are presented in Table 8 of Appendix G.

Table 1
Impact of OTC regulations on methamphetamine lab seizures.

	Number of labs seized				Lab capacity under 2 oz			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
OTC restriction	−6.71	−5.05	−7.02	−7.30	−4.08	−3.05	−4.73	−4.92
	(1.52)	(1.44)	(1.87)	(1.93)	(0.90)	(0.89)	(1.31)	(1.36)
Mean prior to OTC restriction	13.94	13.94	13.94	14.46	9.59	9.59	9.59	9.93
Observations	3825	3825	3825	3675	3825	3825	3825	3675
Number of states	51	51	51	49	51	51	51	49
	Lab capacity 2 to 8 oz				Lab capacity 9 oz or more			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
OTC restriction	−2.29	−1.76	−1.87	−1.94	−0.34	−0.24	−0.42	−0.44
	(0.55)	(0.47)	(0.56)	(0.58)	(0.22)	(0.19)	(0.21)	(0.21)
Mean prior to OTC restriction	3.25	3.25	3.25	3.38	1.10	1.10	1.10	1.15
Observations	3825	3825	3825	3675	3825	3825	3825	3675
Number of states	51	51	51	49	51	51	51	49
Linear state trends	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Quadratic state trends	No	No	Yes	Yes	No	No	Yes	Yes
Covariates	No	No	No	Yes	No	No	No	Yes

Notes: All regressions include state fixed effects and year/month fixed effects. The dependent variable in the regressions is count of labs seized or discovered in a month in a particular state. These are derived from the National Clandestine Laboratory Seizure System. The estimates include records for all 50 states and the District of Columbia from January 2002 through March 2008 [$(6 * 12 + 3) * 51 = 3825$]. Covariates include the unemployment rate, number of households receiving food stamps, average temperature and precipitation. In the fourth specification we drop 150 observations because weather data is missing for Alaska and Hawaii. Standard errors clustered by state are in parentheses.

where β_j is an estimate of the reduction in the number of labs in group j, $E[DiscoveredLabs|PreOTC, Capacity_j]$ is the average number of discovered labs in group j conditional on no OTC restriction being in place, and $Capacity_j$ is the midpoint of the productive capacity interval for group j.[31] We estimate that the OTC restrictions reduced total methamphetamine production capacity within a state by 26%.[32]

We next estimate the impact of the OTC restrictions on the purity and price of methamphetamine.[33] Fig. 4 documents changes in the average nominal price per gram and purity of methamphetamine over our sample period. For efficiency, we weight both series by the number of transactions used to compute the average outcome in each state and month. There is no clear shift in the nominal price per gram at any time between 2002 and 2008. While there is a large drop in the average purity of methamphetamine at the end of 2005, there are also other large changes in average purity before states enacted the regulations.

Fig. 5 presents the event studies for price and purity and Table 2 displays estimates from the corresponding regressions. The figure shows no increase in the nominal price of methamphetamine. The purity measure if anything increases after the introduction of the regulations. The regressions confirm the event study. The point estimates imply a change in the average price per gram ranging from $2.89 to −$1.83, depending on specification. This is a small change relative to the pre-intervention mean of 49 dollars per gram. Across specifications, none of these estimates are significant at conventional levels. We estimate small increases in the purity of methamphetamine of between 7 and 10% of the pre-regulation average purity level, though the estimates are only significant at the 10% level in the specifications that control for state-specific trends.[34]

[31] We evaluate the capacity of labs in the largest group at the left endpoint of 20 lbs.

[32] Our results are fairly robust to using measures of the capacity of each group of labs other than the midpoint. If we measure the lab capacity at the 25th percentile instead of the midpoint, the estimated overall decline shrinks to 23%. Measuring capacity at the 75th percentile of each capacity interval increases the estimated decline to 28%. If we set the statistically insignificant estimates of the effect on larger labs to zero and use the midpoint of each range as the capacity, the estimated decline in capacity is 17%.

[33] Prior work (Dobkin and Nicosia, 2009) documented that a very large, sudden, and unexpected reduction in the availability of a precursor led to a temporary reduction in the purity of methamphetamine and an increase in its price.

[34] In Appendix N we show that there were no effects of the OTC restrictions on the prices or purity of cocaine, crack, or heroin. This is unsurprising given there is no evidence that the laws changed the price or purity of methamphetamine.

The reduction in the number of labs discovered is compelling evidence that state OTC regulations disrupted local production of methamphetamine. The extent to which this disruption affects consumption depends on how much of the methamphetamine consumed in a state is locally-produced as opposed to imported from other states or countries (e.g. Mexico) and how rapidly producers from other regions mobilized to meet the unfilled demand.

5.2. Methamphetamine use

We rely on drug test results to construct measures of methamphetamine consumption. The half-life of methamphetamine in the body is 9–12 hours and urine tests will typically return a positive test if the person consumed methamphetamine in the prior 3 to 5 days. Though the detection window is sensitive to the amount consumed given the relatively short half life, even a 50% reduction in the amount of methamphetamine consumed should only reduce the period over which the use can be detected by 9–12 hours.

We utilize two sources of drug tests in this study. The first source includes work-related drug tests conducted on employers' behalf by Quest Diagnostics. The workplace drug tests are not administered to a random sample of workers. Although some of the tests are random, the majority of the tests are conducted for a particular reason such as pre-employment screening, accidents, or “for cause”. Tests that are done “for cause” are more likely to return a positive finding than tests conducted for other reasons. Not all employers test their employees. About 20% of employee drug tests in this series are from federally-mandated safety-sensitive workers while the remainder are from firms that have chosen to test their employees. The second source of drug tests is hospital records. These are tests of people admitted as inpatients where either the patient reported drug use or the clinicians decided to test patients based on their symptoms. The downward bias that results from the fact that physicians choose to test only a subset of patients is likely to be modest, as there is evidence that doctors do a good job of detecting drug use.[35]

[35] In a randomized trial, Schiller et al. (2000) find that in an urban psychiatric emergency room only 8% of people that had used drugs recently did not have a drug test ordered for them by the doctor treating them. The bias is likely to be even larger for methamphetamine, as its use is more heavily stigmatized.

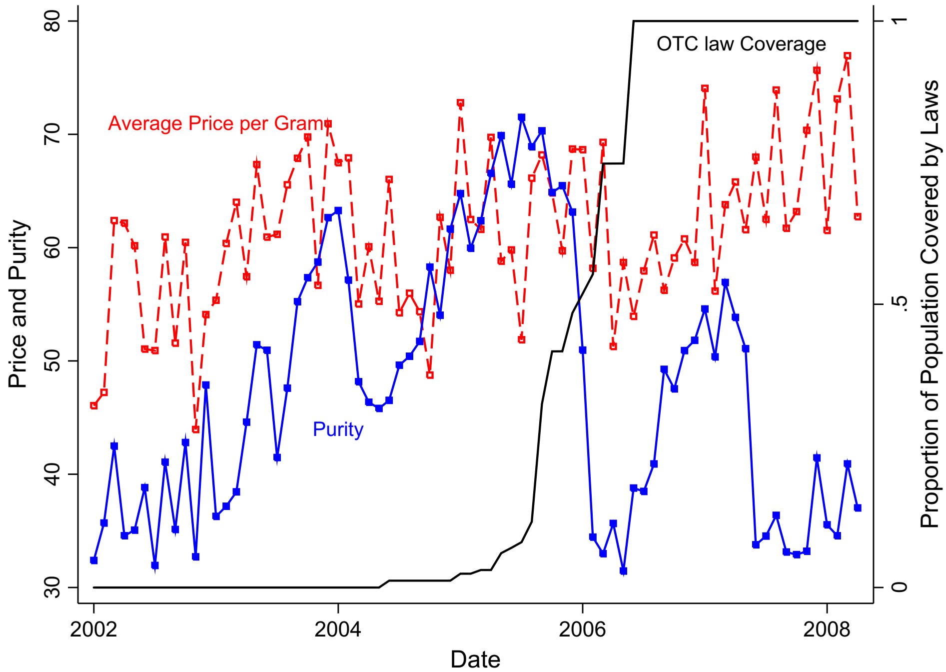

Fig. 4. Price and purity of methamphetamine from STRIDE. Notes: price is measured in dollars and purity is measured in percent. The time series contains averages of the average price per gram and purity of drugs purchased by the police in a state by month.

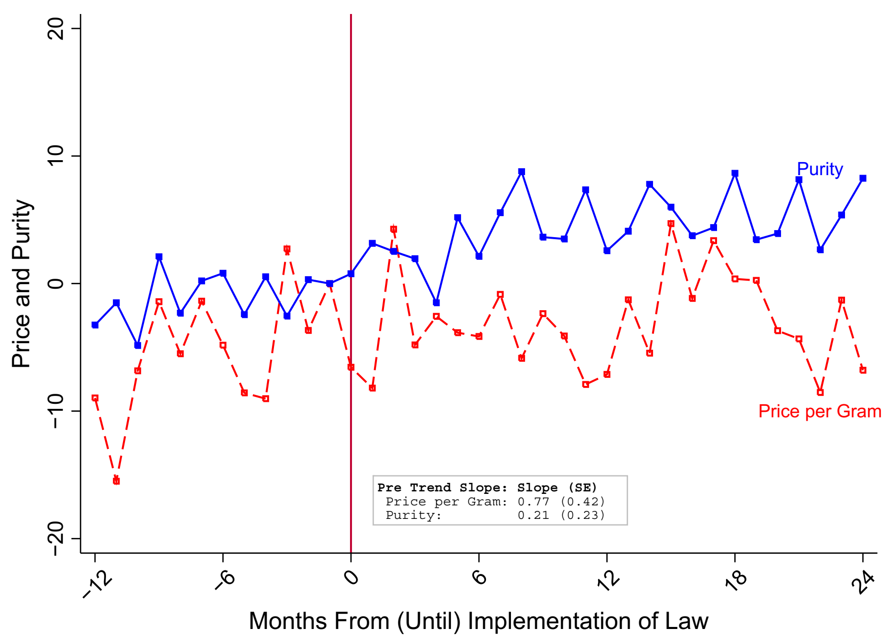

Fig. 5. Price and purity of methamphetamine from STRIDE, event study. Notes: price is measured in dollars and purity is measured in percent. Average price and average purity were regressed on state fixed effects, year/month fixed effects, linear state time trends, and indicators corresponding to the number of months since any over the counter restriction went into effect. The regressions were weighted by the number of illegal drug transactions used to derive the average price and purity measures in a state/month. The graph contains OLS estimates of the coefficients on the indicators corresponding to the number of months since any over the counter restriction went into effect. The coefficients were normalized so the effect on the event dummy equal to one if a state enacted any OTC restriction in the next month is zero. The estimates include records from the District of Columbia and all 50 states except for Nebraska for January 2002 through March 2008. In many smaller states there are months without any purchases.

A more significant issue with measures of consumption generated from the hospital data is that people who experience an inpatient hospital stay are not representative of the general population.[36]

[36] In Fig. 1 of Appendix D we show that both workplace drug test and hospital positive test rates for methamphetamine are strongly correlated with the rate at which people report having used methamphetamine in the past 12 months in the National Survey on Drug Use and Health.

We now turn to examining the impact of the OTC regulations on the rate at which individuals test positive for methamphetamine use in workplace and hospital drug tests. Fig. 6 shows that the percentage of people testing positive for methamphetamine in workplace drug tests and hospital toxicology tests was slowly growing from 2002 through 2005. The upward trend for hospital drug test rates broke sometime in the end of 2005 and by the end of 2007 the positive test rate was the same as it was at the beginning of 2002. The workplace drug test data

Table 2
Impact of OTC regulations on drug price and purity.

	Price per gram				Purity			
	Methamphetamine				Methamphetamine			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
OTC restriction	2.89	2.19	−1.83	−2.12	6.15	4.49	3.81	4.18
	(2.94)	(2.93)	(3.54)	(3.57)	(2.58)	(2.55)	(2.24)	(2.26)
Mean prior to OTC restriction	49.13	49.13	49.13	48.60	56.64	56.64	56.64	56.32
Observations	2074	2074	2074	1995	2074	2074	2074	1995
Number of states	49	49	49	47	49	49	49	47
Linear state time trends	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Quadratic state time trends	No	No	Yes	Yes	No	No	Yes	Yes
Covariates	No	No	No	Yes	No	No	No	Yes

Notes: All regressions include state fixed effects and year/month fixed effects and were weighted by the number of purchases used to construct the outcome in each state/month. The dependent value in the regressions is average price and average purity over the month of drugs purchased by law enforcement. Price is measured in dollars and purity is measured in percent. These are derived from the National Clandestine Laboratory Seizure System. The estimates include records from the District of Columbia and all 50 states except for Nebraska for January 2002 through March 2008 [$(6 * 12 + 3) * 50 = 3750$]. In many smaller states there are months without any purchases particularly for heroin and methamphetamine. Covariates include the unemployment rate, number of households receiving food stamps, average temperature and precipitation. Weather data is missing for Alaska and Hawaii. Standard errors clustered by state are in parentheses.

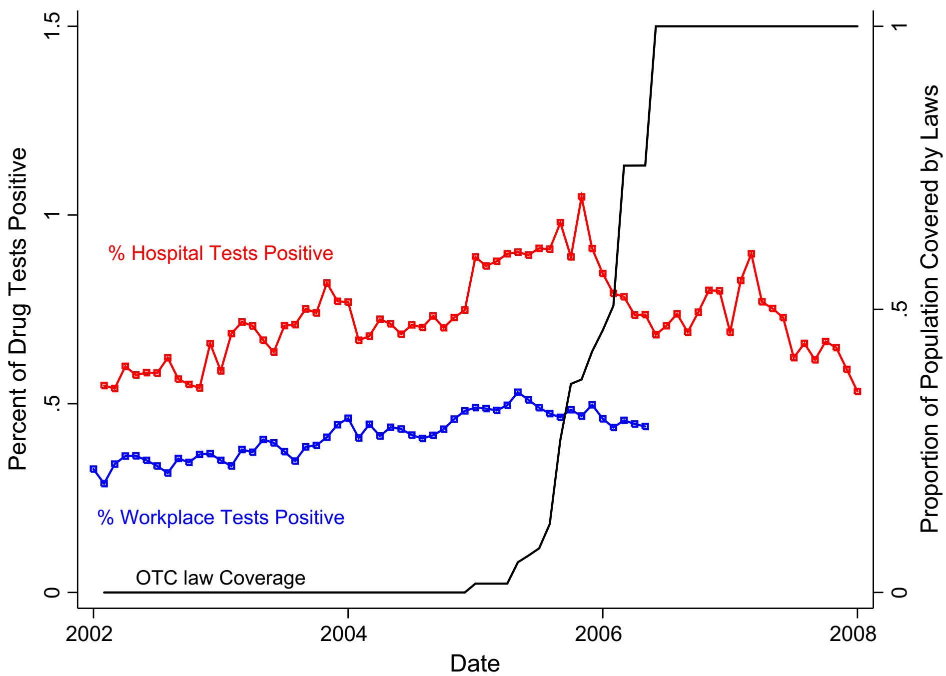

Fig. 6. Percentage of workplace and hospital drug tests positive for amphetamines. Notes: the time series contain the average percentage of positive workplace drug tests and the average percentage of hospital discharge statements with an indication of methamphetamine in a state by month. The workplace drug test data was extracted from the Office of National Drug Control Policy report “Pushing Back Against Meth”. It was downloaded on February 2, 2007 from www.whitehousedrugpolicy.gov/publications/pdf/pushingback_against_meth.pdf. The hospital drug test data is derived from the HCUP NIS which includes a 20 percent sample of community hospitals from the following states AR, CA, CO, CT, GA, HI, IL, IN, KS, KY, MA, MD, MI, MN, MO, NC, NE, NH, NV, NY, OH, OR, SC, TN, TX, UT, VT, WI, and WV and 100% of the community hospitals from AZ, NJ, and WA. For Iowa it is a 20 percent sample before 2004 and all community hospitals from 2004 to 2007. About 90% of hospital stays occur at community hospitals. The series are weighted by state population. The unweighted time series have similar shapes but are more variable.

covers a shorter time period than our other datasets, with an endpoint of April 2006, but the average positive workplace drug test stopped increasing in late 2005. Fig. 7 presents the results of the event studies. While there is no obvious pre-trend in the conditional average positive test rates, there is also no change after the enactment of the OTC regulations. This is supported in each specification of our regressions, which are presented in Table 3. Each specification estimating the effect on workplace drug tests yielded a fairly precise estimate near zero. Column 2, which refers to the specification with the same controls as Fig. 7, contains a point estimate of essentially zero. The standard error implies a 95 percent confidence interval with end-points that are less than 10% of the average positive test rate prior to when the OTC restrictions were enacted. We also find no significant impact of the regulations on positive hospital toxicology test rates, though our estimates are less precise than they were for the workplace drug tests.[37]

5.3. Drug-related arrests

Even though the OTC restrictions did not significantly reduce our measures of methamphetamine consumption, the restrictions may have had an effect on drug-related arrests given their large impact

[37] Because none of the point estimates of the effect of the laws on methamphetamine consumption are significantly different from zero at conventional levels, it is unsurprising that positive test rates for opioids, cocaine, and marijuana were unchanged as well. These results are presented in Appendix N.

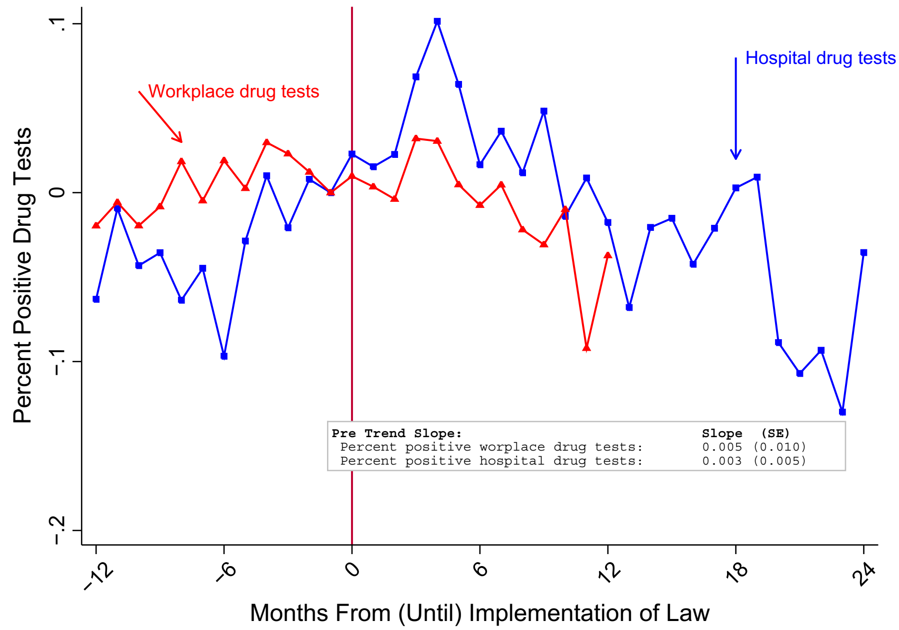

Fig. 7. Event study: percent of workplace and hospital drug tests that are positive for amphetamines. Notes: percentage of positive tests was regressed on state dummies, year/month fixed effects, state time trends, and indicators corresponding to the number of months since any over the counter restriction went into effect. The regressions were weighted by state population. The graph contains OLS estimates of the coefficients on the indicators corresponding to the number of months since any over the counter restriction went into effect. The coefficients were normalized so the effect on the event dummy equal to one if a state enacted any OTC restriction in the next month is zero.

Table 3
Impact of OTC regulations on methamphetamine consumption.

	Percent workplace Tests positive				Percent hospital Tests positive			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
OTC restriction	0.016	−0.0095	−0.0079	−0.0093	0.11	0.083	0.060	0.074
	(0.016)	(0.018)	(0.017)	(0.017)	(0.093)	(0.091)	(0.057)	(0.055)
Mean prior to OTC restriction	0.365	0.365	0.365	0.362	0.671	0.671	0.671	0.656
Observations	2652	2652	2652	2548	2316	2316	2316	2244
Number of states	51	51	51	49	33	33	33	32
Linear state time trends	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Quadratic state time trends	No	No	Yes	Yes	No	No	Yes	Yes
Covariates	No	No	No	Yes	No	No	No	Yes

Notes: All regressions include state fixed effects and year/month fixed effects and were weighted by state population. The data used to construct the percentage of workplace drug tests that were positive is extracted from the Office of National Drug Control Policy report "Pushing Back Against Meth". It was downloaded on February 2, 2007 from www.whitehousedrugpolicy.gov/publications/pdf/pushingback_against_meth.pdf. The estimates include records from the District of Columbia and all 50 states for January 2002 through April 2006 [$(4 * 12 + 4) * 51 = 2652$]. The percentage of positive hospital tests is derived from the HCUP NIS which includes a 20 percent sample of community hospitals from the following states AR, CA, CO, CT, GA, HI, IL, IN, KS, KY, MA, MD, MI, MN, MO, NC, NE, NH, NV, NY, OH, OK, OR, SC, TN, TX, UT, VT, WI, WV and 100% of the community hospitals from AZ, NJ and WA. For Iowa it is a 20 percent sample before 2004 and all community hospitals from 2004 to 2007. Approximately 90% of hospital visits occur at community hospitals. The hospital records do not distinguish positive tests from methamphetamine from positive tests from amphetamine. In this period over 90% of positive tests for either methamphetamine or amphetamine are due to methamphetamine. The estimates include records for January 2002 through December 2007. Covariates include the unemployment rate, number of households receiving food stamps, average temperature and precipitation. Weather data is missing for Alaska and Hawaii. Standard errors clustered by state are in parentheses.

on local methamphetamine production. If the reduction in the number of labs led to fewer people selling methamphetamine, then we may observe a decline in the arrest rate for drug sales. In this section, we examine the impact of the OTC restrictions on drug-related arrests.

Fig. 8 plots the average monthly arrest rates per 10,000 person years for sales and possession of dangerous non-narcotics, which includes methamphetamine, and addicting narcotics. The arrest rate for possession of both types of drugs increased over the beginning of our sample window, but fell concurrently with the enactment of the laws.

The regression estimates reveal that the reduction in arrests for possession in Fig. 8 were driven by common changes across all states. Fig. 9 presents the event studies for drug-related arrests. The event study reveals no clear change in any of the arrest rates after the law. The regressions are presented in Table 4. None of our specifications provide evidence that the restrictions reduced the drug related arrest rates, though some of the estimates are not very precisely estimated. While a few of the specifications provided significant point estimates for the sale of addicting narcotics, the findings are not robust across specifications so we do not view this as persuasive evidence that the restrictions caused a change in drug-related arrest rates.

5.4. Robustness

A potential concern with our research design is that the some retailers may have complied before the laws were enacted. In fact, newspaper reports document that several large retail chains planned to implement the regulations nationwide around August 2005 even

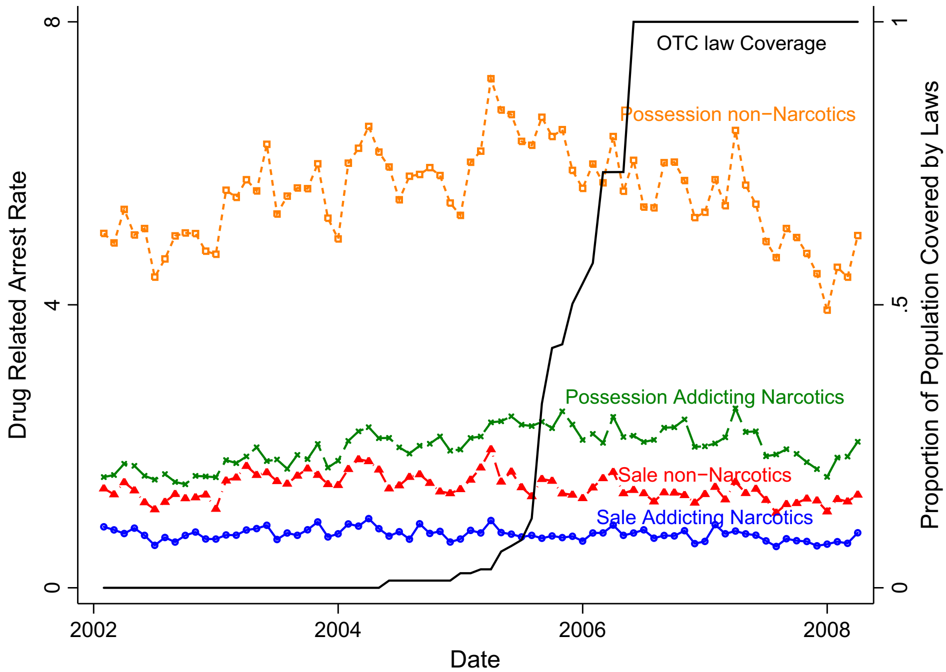

Fig. 8. Drug related arrest rate from uniform crime reports. Notes: the series above are derived from the Uniform Crime Reports for January 2002 through December 2007. There is no data available for Alabama, Florida, and Rhode Island. Records from agencies in some states that report either annually or biannually have been dropped.

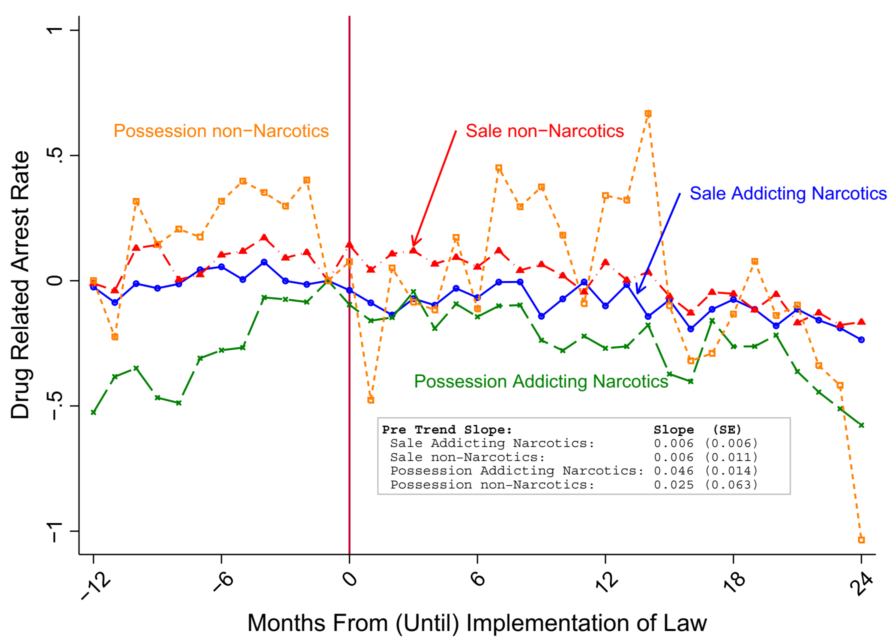

Fig. 9. Event study: arrests for selling addictive narcotics from uniform crime reports. Notes: drug related arrest rates in a month per 10,000 people were regressed on state fixed effects, calendar time effects, state time trends, and indicators corresponding to the number of months since any over the counter restriction went into effect. The regression was weighted by state population. The graph contains OLS estimates of the coefficients on the indicators corresponding to the number of months since any over the counter restriction went into effect. The coefficients on the dummy variables were normalized so the effect the month prior to enacting an over-the-counter restriction was zero. The series above are derived from the Uniform Crime Reports for January 2002 through December 2007. There is no data available for Alabama, Florida, and Rhode Island. Records from agencies in some states that report either annually or biannually have been dropped.

though the regulations had only been enacted in a limited number of states at the time [38] If these plans were carried out, then any information leveraged from late adopting states would bias our estimates downward. We believe this is an unlikely explanation for our results because late adopters were less likely to have substantial methamphetamine problems. Nevertheless, we consider alternative specifications that focus more on the early adopters to provide further support for our conclusions.

Fortunately, 22 states enacted their laws before August 2005, the date several retailers planned to enact the law according to newspaper accounts. We explored the possibility that our main specification underestimates the effect of the law due to early retailer compliance by estimating three different specifications that focus on these 22 states. We did this by

[38] Large retailers who planned on voluntarily imposing restrictions nationwide in July and August of 2005 include: Albertsons/Savon, CVS, Longs Drugs, Kmart, Rite Aid, Target, Walgreens and Walmart: http://www.signonsandiego.com/uniontrib/20050507/news_1b7pseudo.html (last accessed January 6, 2013) and Sam's Club: http://www.msnbc.msn.com/id/7633871/ns/health-cold_and_flu/t/wal-mart-restrict-sales-cold-medicines/ (last accessed January 6, 2013).

Table 4
Impact of OTC regulations on drug related arrests.

	Sales of addicting narcotics				Sales of dangerous non-narcotics			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
OTC restriction	−0.059	−0.066	−0.14	−0.13	0.014	0.013	−0.059	−0.061
	(0.057)	(0.046)	(0.045)	(0.049)	(0.087)	(0.088)	(0.060)	(0.062)
Rate per 10,000	0.726	0.726	0.726	0.728	1.746	1.746	1.746	1.745
Observations	3477	3477	3477	3327	3477	3477	3477	3327
Number of states	47	47	47	45	47	47	47	45
	Possession of addicting narcotics				Possession of dangerous non-narcotics			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
OTC restriction	0.13	0.13	−0.056	−0.048	−0.26	−0.31	−0.32	−0.27
	(0.12)	(0.11)	(0.099)	(0.11)	(0.91)	(0.93)	(0.44)	(0.43)
Rate per 10,000	1.572	1.572	1.572	1.577	8.409	8.409	8.409	8.428
Observations	3477	3477	3477	3327	3477	3477	3477	3327
Number of states	47	47	47	45	47	47	47	45
Linear state time trends	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Quadratic state time trends	No	No	Yes	Yes	No	No	Yes	Yes
Covariates	No	No	No	Yes	No	No	No	Yes

Notes: All regressions include state fixed effects and month dummies. Standard errors are clustered at the state level. The dependent value in the regressions is arrest rate in a month per 10,000 people in a state. Regressions are weighted by state population. These are derived from the Uniform Crime Reports for January 2002 through December 2007. There is no data available for Alabama, Florida, New York, and Rhode Island. Records from agencies in some states that report either annually or biannually have been dropped. Covariates include the unemployment rate, number of households receiving food stamps, average temperature and precipitation. Standard errors clustered by state are in parentheses.

estimating our base model using data only on states that enacted a law prior to August of 2005. The results, in Appendix H, show that states that enacted a law early in the sample experienced large reductions in the number of laboratories, but no significant change in purity, consumption or arrests for the sale or possession of dangerous non-narcotics.

The estimates presented in this paper were calculated on data that is not balanced in event-time–we do not observe each state for the same number of time periods before and after a law was enacted. We checked that the estimates are not meaningfully different when calculated on data that is balanced in event time. These results are presented in Tables 1–5 of Appendix J.

6. Spillovers across state borders

The research design we implemented above does not allow for the possibility that methamphetamine producers respond to the passage of

Table 5
County level impact of OTC regulations on methamphetamine lab seizures.

	Number of labs seized				Lab capacity under 2 oz			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
OTC restriction	−0.087	−0.093	−0.081	−0.10	−0.057	−0.060	−0.053	−0.071
	(0.026)	(0.032)	(0.032)	(0.032)	(0.015)	(0.019)	(0.020)	(0.022)
OTC restriction ∗ border county		0.046	0.041	0.043		0.036	0.035	0.038
		(0.028)	(0.026)	(0.028)		(0.020)	(0.019)	(0.020)
Border county ∗ neighbor state OTC restriction		0.014	0.0090	0.011		0.018	0.016	0.019
		(0.028)	(0.028)	(0.025)		(0.029)	(0.029)	(0.026)
OTC restriction ∗ border county Neighbor state OTC restriction		−0.061	−0.046	−0.052		−0.057	−0.048	−0.055
		(0.032)	(0.031)	(0.030)		(0.032)	(0.032)	(0.031)
p-Value $\beta_{otc} + \beta_{border,otc} = 0$		0.060	0.098	0.025		0.18	0.33	0.10
p-Value \beta$_{\text{border,otc}}$ +\beta$_{\text{neighbor,border}}$+\beta$_{\text{otc,neighbor,border}}$ = 0		0.95	0.89	0.90		0.88	0.87	0.90
Mean prior to OTC restriction	0.23	0.23	0.23	0.23	0.16	0.16	0.16	0.16
Observations	235725	235725	235725	235725	235725	235725	235725	235725
	Lab capacity 2 to 8 oz				Lab capacity 9 oz or more			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
OTC restriction	−0.029	−0.031	−0.026	−0.026	−0.0015	−0.0022	−0.0022	−0.0052
	(0.0076)	(0.0089)	(0.0086)	(0.0090)	(0.0051)	(0.0060)	(0.0050)	(0.0039)
OTC restriction ∗ border county		0.0067	0.0035	0.0046		0.0035	0.0028	0.00035
		(0.011)	(0.011)	(0.011)		(0.0031)	(0.0031)	(0.0040)
Border county ∗ neighbor state OTC restriction		−0.0049	−0.0059	−0.0049		0.00029	−0.0016	−0.0029
		(0.0051)	(0.0054)	(0.0059)		(0.0044)	(0.0036)	(0.0039)
OTC restriction ∗ border county ∗ neighbor state OTC restriction		−0.0013	0.0039	0.0017		−0.0031	−0.0021	0.0020
		(0.0087)	(0.0085)	(0.0089)		(0.0043)	(0.0045)	(0.0049)
p-Value $\beta_{otc} + \beta_{border,otc} = 0$		0.027	0.019	0.046		0.77	0.87	0.31
p-Value\beta$_{\text{border,otc}}$ +\beta$_{\text{neighbor,border}}$+\beta$_{\text{otc,neighbor,border}}$ = 0		0.94	0.83	0.84		0.81	0.79	0.85
Mean prior to OTC restriction	0.054	0.054	0.054	0.054	0.018	0.018	0.018	0.018
Observations	235725	235725	235725	235725	235725	235725	235725	235725
Linear state trends	No	No	Yes	Yes	No	No	Yes	Yes
Quadratic state trends	No	No	No	Yes	No	No	No	Yes

Notes: All regressions include county fixed effects and year/month fixed effects. The dependent variable in the regressions is count of labs seized or discovered in a month in a particular county. These are derived from the National Clandestine Laboratory Seizure System. The estimates include records for all 3143 county FIPS areas (excluding Puerto Rico) from January 2002 through March 2008 [$(6 * 12 + 3) * 3143 = 235{,}725$]. Standard errors clustered by state are in parentheses.

a law restricting access to OTC medicines by purchasing precursors in other states or by moving methamphetamine production out of state. This approach will recover estimates of the effect of a state passing a law when there is a mix of treated and untreated states surrounding it, which is the treatment effect that state legislators have available to them when they are considering passing legislation. However, to get estimates of the effect of restricting the sale of OTC medicines nationally we need to estimate the amount of evasion that is occurring and adjust for it. It is not feasible to allow for arbitrary patterns of evasion, so we model spillovers in counties that are located on state borders. This is reasonable because the cost of moving precursors or production is a function of distance and most criminal networks are likely local. We assume that methamphetamine production in non-border counties is not affected by spillovers and fit the following equation to the data using OLS:

$$\begin{aligned} Labs_{ct} = {} & \alpha OTC_{ct} + \beta OTC_{ct} * BorderCounty_c \\ & + \gamma BorderCounty_c * NeighborStateOTC_{ct} \\ & + \delta BorderCounty_c * NeighborStateOTC_{ct} * OTC_{ct} \\ & + \eta_c + \zeta_t + \epsilon_{ct} \end{aligned} \tag{5}$$

where OTC_{ct} takes on a value of 1 if the state that county c is in has a law in month t and 0 otherwise. $BorderCounty_c$ takes on a value of 1 if county c borders another state and 0 if not. $NeighborStateOTC_{ct}$ takes on a value of 1 if county c shares its border with a neighboring state that has an OTC restriction during month t and zero if the neighboring state does not.[39] η_c and ζ_t are county and year/month fixed effects, respectively.

The coefficients of interest are α, β, γ and δ. α gives the effect of an *OTC* restriction on the number of labs discovered per month in non-border counties. $\alpha + \beta$ gives the effect of enacting an OTC restriction on the number of labs discovered in border counties when the neighboring state has no regulation in place. If methamphetamine producers can easily obtain and move precursors across the state border we would expect the effectiveness of the law to be blunted, and β to be positive but less than α in magnitude. γ gives the effect of a state enacting a OTC law on the number of labs discovered in a border county in neighboring state with no regulation in place. If methamphetamine production moves across state borders in response to a law then γ would be positive. $\alpha + \beta + \gamma + \delta$ gives the effect on border counties of a state enacting a law when all neighboring states have a law in place. In this case there is a little scope for displacement of precursors, and we expect the total effect to be similar to that of a non-border county ($\beta + \gamma + \delta$ should be close to zero). Our best estimate of the nationwide effect of the laws, accounting for displacement, is the population weighted average of the effect on non-border counties (α) and the effect on border counties when all the neighbors are treated ($\alpha + \beta + \gamma + \delta$).

The results of estimating Eq. (5) are presented in Table 5. Column 1 presents county level estimates that impose a constant effect across all counties by constraining β, γ and δ to be zero. Column 2 presents the results of estimating the most parsimonious specification 5, and columns three and four add state-specific linear and quadratic time trends, respectively. The results are clear. First, the laws reduced the number of discovered labs in non-border counties by about 40% ($-.093/.23$) of the pre-intervention mean. Second, the effect of the regulations in border counties was blunted by about 50% (.046/.093) when the neighboring state had no regulation in place. Third, there is very little evidence that production moves to a neighboring state without a regulation in response to enactment of a law as the estimate of γ, though positive, is small and statistically insignificant. Finally, once a border county and its neighboring state both have regulations in place the total effect is essentially identical to that of non-border counties. As of March 2008, the most recent time period in our sample, 34% of the US population lived in a border county. This implies a total effect of the laws, accounting for displacement, equal to $-.093$ ($-.093*.66 + (-.093+.046+.014-.061)*.34$), or 40% of the pre-intervention mean. This estimate is also only slightly larger than the 38% reduction relative to the pre intervention mean we observe from the regression in the first column that does not allow for spillovers.[40,41]

In summary, the county level lab evidence suggests that spatial spillovers do exist. The laws had a muted effect in border counties when neighboring states had no law in place. This is likely because methamphetamine producers could obtain precursors from neighboring states where a law was not in effect and bring them back to produce methamphetamine. After the neighboring state enacts a law, the treatment effect for border counties is nearly identical to that of non-border counties and the implied percentage change in the number of discovered labs is similar to our state level regressions that ignore spillovers. We are unable to conduct a county level analysis for price, purity, consumption or arrests due to data limitations. This is not as substantial a problem as it might appear as the examination of the labs suggests that not explicitly accounting for evasion will have only a small effect on those estimates.[42]

7. Interpretation and conclusion

The effectiveness of supply-side enforcement efforts targeting illegal drugs has been widely-debated (Grossman et al., 2002). Difficulties in estimating the effects of enforcement efforts are well known, and have compelled researchers to turn to quasi-experimental methods to address some of the limitations of a previous research. The OTC regulations examined in this paper are part of a series of precursor regulations, but variation in the timing of implementation across states provides a unique opportunity to estimate their impact on drug prices and consumption. In this paper, we link changes in each state's regulatory environment with changes in the production of methamphetamine. The OTC laws successfully disrupted local methamphetamine production with the number of labs in the state declining by about 40%. We estimate reductions in laboratories of all sizes, but the largest and most significant reductions were among the smaller laboratories. The laboratory series fails to show signs of recovery during the first year after the laws were enacted.

Despite the large reduction in the production of methamphetamine within a state, we find no evidence of reductions in methamphetamine purity, consumption, or arrests. One potential explanation consistent with our results is that small labs comprise a minority of methamphetamine supply and that production may have shifted outside the U.S. This is consistent with DEA evidence that production capacity migrated around the time the state laws were enacted. While it is difficult to precisely estimate the share of methamphetamine that comes from abroad, one study estimates that the share of methamphetamine produced in large labs that are primarily found in Mexico increased from 65% in the period before state laws were implemented to 80% afterwards.[43] The amount of methamphetamine seized at the Southwest border of

[39] In instances where the county c shares a border with multiple states $NeighborStateOTC_{ct}$ was coded as the fraction of neighboring states that had a law in place at time t.

[40] Despite the evidence that when evasion is possible there is a substantial flow of precursors across state borders, accounting for evasion only changes the estimates modestly because in many states for much of the post period all the neighbors are treated and there is no possibility of evasion.

[41] Appendix M presents results from the county level analysis estimated with Poisson models.

[42] Appendix K presents time series of the average of each of our outcomes for the states that adopted because of the federal law. While these states should not be affected by spillovers, we are reluctant to draw any inference from them because it is unlikely the time series would have been stable in the absence of the law.

[43] These estimates were taken from the interim report of the Synthetic Drugs Interagency Working Group: https://www.ncjrs.gov/ondcppubs/publications/pdf/interim_rpt.pdf, last accessed 12/31/2012.

the United States and the number of laboratories seized in Mexico also increased from 2004 to 2006 by 19 and 35%, respectively.[44]

We also find indirect evidence that methamphetamine producers in border counties responded to the OTC laws by purchasing precursors in neighboring states that did not have a law in place. This reduced the effectiveness of the laws and is perhaps not surprising given the very low risk of purchasing and transporting a legal product. We find little evidence that producers relocated production across state borders possibly due to the cost of acquiring a location to produce methamphetamine in an area in which they do not live and the risk of transporting an illegal substance. These findings suggest that state legislators should consider the ease with which people can circumvent state laws by crossing borders when designing legislation meant to prevent an activity.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jpubeco.2014.07.011.

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[44] These estimates were taken from the Department of Justice's National Drug Intelligence Center National Drug Threat Assessment of 2010, available at http://www.justice.gov/archive/ndic/pubs38/38661/38661p.pdf, last accessed 1/2/2013.