Mandatory Minimum Sentencing, Drug Purity,

and a Test of Rational Drug Use

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Abstract: As of 1987, the Anti-Drug Abuse Act (ADAA) has imposed mandatory minimum sentences for drug traffickers based on the quantity of the drug involved regardless of its purity. Using the STRIDE dataset on drug arrests and a differences-in-differences approach, I find that this led to an increase in cocaine purity of 42% and an increase in heroin purity of 30%. Using data on emergency room visits, I show that the concurrent rise in drug-related ER episodes is due to the rise in the standard deviation of drug purity rather than the increase in average purity. Estimates suggest that the increases in standard deviations at the time of the ADAA translate to increases in cocaine and heroin ER mentions of 15% each. Because these negative outcomes depend only on the standard deviation of purity, this suggests that drug users respond rationally by reducing the quantity consumed in response to anticipated increases in the purity of these drugs. Finally, again using the STRIDE data, I find that the ADAA is associated with an increase in the standard deviation of cocaine purity, implying more cocaine ER mentions.

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1. Introduction

Although drug use has long been viewed as a problem, worries continue to mount as the potency of many illicit substances rise. As the Drug Enforcement Agency (DEA) warns, marijuana today is far more potent than that of thirty years ago and "the more THC [the psychoactive chemical in marijuana], the more potent and dangerous the "weed" is".[1] As shown in Figure 1, comparable changes have occurred in the average purity of street-level cocaine and heroin. Concurrent with this rise in purity, the number of emergency room (ER) visits mentioning these drugs have has increased as well. As illustrated in Figures 2 and 3, the number of ER visits per 100,000 mentioning cocaine or heroin doubled during the 1990s. This suggests that there may be a causal link in which more powerful drugs increase the likelihood of accidental overdose.[2] This link, however, poses a problem. Presuming that an overdose is an unintended consequence of use, why do drug users not reduce the quantity consumed as average purity rises? If users do not respond to anticipated changes in drug purity, this calls into question the appropriateness of using economic models that assume that users are rational.

In response to this concern, this paper does three things. First, it demonstrates that a large part of the increase in cocaine and heroin purity is due to the 1986 passage of the Anti-Drug Abuse Act (ADAA). This law introduced federal mandatory minimum (MM) sentences based on the quantity of drugs seized, regardless of their purity. Second, it asks whether there is indeed a significant link between increasing purity and increasing ER visits. I find that the increase in ER visits resulted from increases in the standard deviation of purity rather than the increases in average purity. This suggests that,

[1] Taken from DEA (2005), http://www.dea.gov/pubs/straight/mari.htm.
[2] Examples of such claims include DEA (2005) and Hall and Darke (1997).

consistent with standard economic assumptions, drug users do indeed respond to anticipated changes in purity but are unable to fully avoid the problems caused by increased uncertainty over purity. Third, I show that the ADAA increased the standard deviation of cocaine purity and therefore may have increased cocaine ER mentions. For heroin, federal MMs appear to have had no significant effect.

According to the Office of National Drug Control Policy, in 2003 the U.S. federal government spent over $19 billion on the war on drugs. This is in addition to the billions spent by local law enforcement and the criminal justice system. An increasingly important component of these costs is the need to house offenders. Currently, over one million people are incarcerated in the U.S. due to drug offences (DOJ, 2004). This large number is due to both increased interdiction efforts and stiffer penalties for convicted offenders. One of the most important penalty increases for drug trafficking was the 1986 passage of the ADAA which, among other provisions, introduced federal MMs for drug trafficking.[3] These MMs set forth penalties that the federal judge must impose upon conviction.[4] The data suggest that penalties have indeed risen. Trial defendants facing MMs are two and a half times likely to be convicted (Jaffe, 1995).[5] Furthermore, between 1986 and 1991 the average federal prison sentence for a drug offense rose from 62 to 86 months with the percentage of time served increasing by thirteen percent (BJS, 1995). As

[3] These laws took effect in 1987 and include the United States Code Section 21 Subsections 841, 844, and 960, which govern the manufacture, distribution, possession, and import/export penalties for controlled substances. For details and discussion of this Act, see Saphos, et. al. (1987). According to Lay (2004), a recently-passed Senate measure seeks to increase these sentences, including a mandatory life sentence for second-time offenders. In addition to federal mandatory minimums, many states have similar schemes that apply to cases tried in their own courts. One of the best known, the so-called Rockefeller Drug Laws, were enacted in New York in 1973.

[4] These laws do allow for two exceptions. The Violent Crime Control and Law Enforcement Act of 1994 allows non-violent first time offenders to receive reduced sentences (BJS, 2001). In addition, those offering "substantial assistance" to law enforcement can obtain reduced sentences. According to the BJS (2001), this accounted for about 28% of cases in 1999.

[5] During 1999, 62% of drug convictions were under mandatory minimums with over half receiving sentences of more than sixty months (BJS, 2001).

Table 1 shows, the severity of the MM is increasing in the amount of the illicit drug that is involved in the conviction. What is surprising, however, is that the sentence is based on the total weight of what is captured, not on the "pure" weight, that is, the amount of the drug that is left after netting out adulterating substances.

According to the federal MMs, someone convicted of selling five kilos of ten percent pure cocaine would receive a minimum of ten years in jail but someone convicted of selling four kilos of 100 percent pure cocaine would only a receive a five year sentence.[6] One example of these laws in practice is the case of Prem Atri, who was convicted of trafficking LSD in 1989 (Nichols, 1999). Although he was only found in possession of 3.3 grams of actual LSD, it was combined with 433.6 grams of blotter paper. This combined weight carried a mandatory minimum sentence of ten years, while if the LSD had been in liquid form, it would have only warranted a five year sentence. By enforcing minimum sentences based upon the total weight of a mixture containing an illegal substance rather than on the amount of the substance alone, this increases the cost of delivering a given quantity of drugs. The predicted response to this is clear: to avoid harsher penalties and higher costs, both consumers and producers would prefer to trade in smaller, purer amounts. The United Nations Office for Drug Control and Crime Prevention (1999) finds that drug traffickers do indeed respond to market changes, including increases in their perceived risk suggesting that such an effect may well exist.

This paper demonstrates such a change in response to MMs using 1977 to 2001 data from the DEA's System to Retrieve Information from Drug Evidence (STRIDE) database. This dataset contains information on drug arrests by the Federal Bureau of

[6] Furthermore, 500 grams of pure powder cocaine yields a sentence only 1/20th of what an equal amount of crack cocaine (which by definition cannot be pure) would earn.

Investigation (FBI) and the DEA, including the purity of the seizure. As Figure 1 illustrates for observations involving one gram or less, the purities of both cocaine and heroin have been rising over the past twenty-five years, with a remarkable change in the trend following the imposition of MMs in 1987. After controlling for a number of factors, these data suggest that the imposition of MMs increased the purity of cocaine by approximately 25.8 percentage points, an increase of about 42 percent. Similarly, the data suggests that MMs increased heroin purity by 8.6 percentage points, an increase of around 30 percent. It is notable that these increases were not mirrored in other countries. Using the STRIDE's international observations, I do not find an increase in the purity of cocaine or heroin purchased outside the U.S. after the MMs took effect. Similarly, Pianca (1998) found that the average purity of heroin seized in the Australian Capital Territory between 1980 and 1992 stayed steady at approximately 20 percent. According to the STRIDE data, during the same period heroin seizures in the U.S. rose in purity from 11.7 percent to 43 percent. It is also worth noting that, although I do not analyze other drugs due to data availability, anecdotal evidence suggests that a comparable effect would be found. For example, the average THC content of marijuana (the psychoactive substance in the drug) rose from one percent in the mid-1970s to six percent in 2002 (ONDCP, 2004).[7] Similarly, Miron and Zwiebel (1991) document a comparable shift from beer and wine towards spirits during America's alcohol prohibition.

An important aspect of this increase is that it varies by state. In particular, as Table 2 details, several states had imposed their own state-level MMs prior to the federal law. As such, one might expect that the increase in purity in response to the federal law

[7] It should be noted that the factors affecting cocaine and heroin purity differ from those affecting marijuana purity.

would be smaller in these states because dealers may have already shifted towards higher purities in response to the state-level MM. Table 3 reports the average purity for drug deals of one gram or less both before and after 1987 as well as depending on whether the state had its own MM. As can be seen (and as is confirmed in the regression analysis), this increase is indeed smaller for states with their own pre-existing MMs. This difference-in-differences approach helps to alleviate the concern that the regression analysis is merely capturing a trend in the overall data since this would require that the break in the trend differed by state. Furthermore, for the estimated impact to solely reflect changes such as the introduction of crack or a change in the type of dealers the DEA targets, this too would have to be demarcated along state-level MM lines.

One obvious impact of MMs is that they necessitate housing offenders for longer periods. In addition, because of their impact on purity, MMs can lead to other unintended costs. First, more pure heroin can be ingested nasally or through smoking. This increases the attractiveness of the drug for those who are unwilling to inject it intravenously. As a result, as the DEA notes, higher purity levels seem to be associated with more heroin users (DEA, 1999). In addition to its impact on the number of users, increased purity may well affect the outcome of use. Looking at data from the Drug Abuse Warning Network (DAWN), the number of ER episodes mentioning the use of cocaine or heroin have risen along with the average purity. Hall and Darke (1997) suggest that the increase in heroin overdoses in Australia during the mid-1990s was linked to the increase in purity. However, if users are rational, one would expect them to condition the quantity they consume on the anticipated purity of the drug in their possession. This is because as average purity rises, a user can consume a smaller quantity and achieve the desired high without increasing their anticipated risk of overdose.[8] As such, if there is indeed a significant correlation between average purity and overdoses, this casts doubt on the appropriateness of modeling drug users as rational economic agents. It is therefore important to determine whether there is indeed a significant link between average purity and overdoses.

I find that average purity does not appear to be robustly correlated with hospital mentions. Instead, for both cocaine and heroin, I find that the concurrent rise in the standard deviation of purity appears to be behind the rise in ER mentions. Given my estimates, I find that the increase in the standard deviation of cocaine and heroin between 1986 and 1987 would be associated with an estimated increase in emergency room (ER) mentions for cocaine and heroin of 772 and 377 per 100,000 respectively. Compared to the sample means, these correspond to increases of 15 percent and 15.4 percent respectively. Furthermore, I find that an increase in the standard deviation of one drug is positively correlated to ER mentions attributed to the other drug, suggesting that uncertainty regarding one drug creates substitution towards the other.

Using another, heretofore unused database provided by the DAWN, I find that the standard deviation of purity is also positively correlated with the number of overdoses and unexpected reactions from heroin and cocaine use. I furthermore find that number of deaths from cocaine use is positively correlated with the standard deviation of cocaine purity. This is not found for heroin. This is consistent with the fact that with repeated use the body becomes more sensitive to the deadly effects of cocaine, an effect that does not

[8] Furthermore, if one were to attribute the rise in ER visits to an increased proportion of adulterants, then one would expect overdoses to fall as purities rise.

occur with opiates such as heroin. Thus, the importance of purity uncertainty is likely to be small for this particular outcome from heroin use.

These results beg the question of whether the increase in standard deviations can be attributed to the introduction of MMs. As illustrated in Figures 2 and 3, using the STRIDE data, I find that the standard deviation of purity did indeed rise following the ADAA. There are certainly reasons to think that this relationship may be causal because of heterogeneous producer responses engendered by the law. Since MMs are twice as large for repeat offenders, these offenders have more of an incentive to increase purity and reduce quantity. Furthermore, different drug dealers may respond differently because of their ability to provide useful information to the government (thereby reducing their sentence). Other potential causes of heterogeneous dealer responses include variation in access to quality legal council and familiarity with the structure of trafficking penalties. Finally, since the incentive to economize on quantity is greater for larger quantities, the ADAA may have shifted the level at which drugs are "cut" or diluted from upper-level dealers to low-level dealers. This decentralization in dilution might then lead to greater variation in purity. As a result of these varied responses to MMs, such laws may well have increased the variance of purity.[9] On the other hand, it seems just as possible that the ADAA, by encouraging higher purities across the board, may lead to less variation in drug purity. Again using the STRIDE data, I find the introduction of federal MMs increased the standard deviation of cocaine purity by 6 percentage points (almost the same as the shift described above). In the heroin market, I find no effect from federal

[9] In addition, it is possible for an increase in the Lemons Problem (Akerlof, 1970) after average purity rises since higher expected purity is correlated with higher prices and therefore a higher incentive to pass off low-quality product. It is worth noting that, as shown in Figures 4 and 5, this does not appear to be the case in my data since the density of low-purity observations falls after 1987.

MMs, although states with preexisting MMs had standard deviations for heroin purity that were 4.4 percentage points higher. Thus although the effect varies between drugs, the evidence indicates that the ADAA did indeed increase the uncertainty of cocaine purity.

The remainder of the paper is laid out as follows. Section 2 provides an overview of the existing literature on illicit drug markets. Section 3 describes the data. Section 4 contains the results regarding the effect of MMs on drug purity. Section 5 investigates the effect of purity changes on ER mentions and outcomes. Section 6 estimates the impact of the ADAA on the standard deviation of purity. Section 7 concludes.

2. Existing Literature

Over the past thirty years, the economic literature on illicit drug markets has had three main themes. First, a number of researchers have sought to model the demand for these substances. On the theory side, this has led to the rational addiction work pioneered by Stigler and Becker (1977) and continued by Spinnewyn (1981), Becker and Murphy (1988), Dockner and Feichtinger (1993), and others. This literature seeks to model the unique properties of addictive substances and create a utility-based theory for why users begin use and display patterns such as escalating consumption. Recent theory has moved towards state-contingent utility theory, including Hung (2000) and Laibson (2001), and cue-conditioned cognition addiction models such as Bernheim and Rangel (2004). In these models, the forward thinking "rational addict" is replaced by a more myopic model of consumption. However, since user behavior can be mathematically modeled, this is still rational behavior. The empirical strand of this theme has focused on estimating the various factors that influence drug use. Chief among these is the attempt to capture the price elasticity of demand since interdiction efforts presumably lead to higher prices and therefore less use (more on this below). Because of data availability, most studies estimate the price sensitivity of cocaine (Grossman and Chaloupka, 1998) and heroin (Silverman and Spruill, 1977; Bretteville-Jensen and Sutton, 1996) or both (Saffer and Chaloupka, 1999).[10] Bach and Lantos (1996) go a different route and estimate the effect of heroin prices on users' demand for methadone treatment. On the whole, this work finds that higher prices decrease demand, although the magnitude of the price elasticity varies.

One study that is particularly important for the current issue is that of Caulkins and Padman (1993), who investigate cocaine users' willingness to substitute between purity and quantity. In particular, they find that this substitution is not perfect. Using the STRIDE drug price data, they find that consumers pay more for two grams of a 30 percent pure drug than for one gram with 60 percent purity. Thus, although drug markets might shift away from quantity towards purity due to MMs, Caulkins and Padman's results suggest that they would not switch to an entirely pure product.

The second strand of the literature focuses on the impact of government policies, particularly those geared at reducing the drug supply. Generally, this is done by isolating the impact of a policy on drug prices. If higher prices reduce drug use, this is one method of capturing the effectiveness of policy. In a search model, Freeborn (2003) theoretically considers the price effects of enforcement, including MMs, on the cocaine market. However, she does not empirically test this effect. Kennedy, Reuter, and Riley (1994) build an extremely detailed model of the cocaine market in order to simulate the price effect of a variety of drug interdiction efforts, including defoliation policies in Columbia.

[10] Exceptions include Nisbit and Vakil's (1972) marijuana study and van Ours's (1995) work with early 20th-century opium consumption data.

As with the price elasticity studies, due to data availability most of the empirical work estimating the effect of government policies has focused on the cocaine and heroin markets. Kuziemko and Levitt (2001), Bushway, Caulkins, and Reuter (2003), DiNardo (1993) and Lee (1993) find that increases in the severity of punishment or the level of law enforcement increase cocaine prices. Rydell and Sohler-Everingham (1994) estimate the cost-effectiveness of interdiction versus treatment programs finding that treatment is a more cost-effective method of reducing drug use. Caulkins, Rydell, Schwabe, and Chiesa (1997) perform a similar analysis for the effects of MM sentences on cocaine trafficking, again finding that treatment is more cost effective.

The third strand of the literature considers the effect of drug use on a variety of outcomes. Examples of this work includes the effect of drug use on educational attainment (Chatterji, 2003), marital stability (Kaestner, 1995), and violence (Fryer, Heaton, and Levitt, 2004). Closer to the current analysis are those studies that estimate the effect of drug prices, as a proxy for drug usage, on drug-related ER mentions. Early work by Caulkins (2001) finds that prices are negatively correlated with ER mentions. Hyatt and Rhodes (1995) include city fixed-effects and find a similar impact for cocaine prices. Dave (2004) criticizes these studies for not including time trends and other correlates. After controlling for these, he too finds a negative correlation between price and ER mentions, both for cocaine and for heroin. Model (1993) finds a comparable negative correlation between marijuana prices and ER mentions of the drug.

It is important to note the crucial role that price data plays in most of the above empirical work. However, not all researchers agree with using STRIDE's price data for economic research. In particular, Horowitz (2001) argues that these data are not representative of typical drug transactions due to sample selection. A clever rebuttal to this criticism is provided by Caulkins (1994), who notes that if there is indeed a large, observable bias in the prices negotiated by law enforcement officers relative to actual users, this should act as a signal to the drug dealer. As such, Caulkins argues that the dealer would then likely walk away without the transaction being completed, thereby excluding the observation from the sample. In any case, I do not use price data as my variable of interest.

On a related note, there is the concern that the dealers themselves are a biased sample, a concern motivated by the possibility that dealers targeted by the DEA are not representative of average dealers. In the context of this paper, if the DEA targets high-purity dealers then the average purity might be higher here than in (unavailable) representative data. This indicates the need to control for unobserved factors by using state-specific fixed effects. However, when asking whether the federal MM increased purity in a differences-in-differences specification, to find the results I do it would be necessary for the DEA to change its priorities in a manner targeting even higher-purity dealers in states without their own MMs at around the same time the federal law took effect. Since there is no documentation to support such a claim, my results give the best indication of the effect of the federal law given the constraints of the available data.

3. Data

The unit of observation in my data is a drug transaction. Specifically, I estimate the following specification:

$$Purity_{i,s,t} = \alpha_0 + \alpha_1 S_s + \alpha_2 T_{s,t} + \alpha_3 X_i + \alpha_4 ManMin_{s,t} + \alpha_5 Z_t + \alpha_6 Y_{s,t} + \varepsilon_{i,s,t}$$

where $Purity_{i,s,t}$ is the purity of transaction *i* which took place in state *s* in year *t*. This is a function of state-specific fixed effects (S_s), state specific linear time trends ($T_{s,t}$), transaction specific variables (X_i), the legal environment in state *s* in year *t* ($ManMin_{s,t}$), state-invariant time-varying variables (Z_t), other state-specific time-varying variables ($Y_{s,t}$), and the error term $\varepsilon_{i,s,t}$.

Information on a drug transaction comes from the DEA's STRIDE database, which contains information on cocaine and heroin arrests by the Federal Bureau of Investigation and the DEA. For this study, I use data from 1977 to 2001 since information from ongoing investigations is withheld by the DEA (this is a problem in the data after 2001).[11][12] For each arrest, the date and location of the arrest is logged as well as the form, quantity, and purity of the drug seized.[13] In my estimates I use powder cocaine and heroin. In addition to the above information, if the arrest followed a completed transaction, the STRIDE data reports the price negotiated for the given amount.[14] Observations with missing information were deleted. International observations were also deleted, thus my sample is composed of observations from the fifty U.S. states plus Washington D.C. (all of which I refer to as "states").[15] The handful of observations with

[11] My data were obtained under the Freedom of Information Act, request number 02-0714-R.

[12] In unreported results, I used sub-samples of the data including the ten and four years surrounding 1987. This yielded similar sign patterns to the reported results, however significance declined along with the large decrease in the number of observations.

[13] A sizable number of observations report zero purity. If these observations are dropped, similar results are found with an estimated coefficient for federal mandatory minimums of 24.6 for cocaine and 8.7 for heroin, both of which are significant at the 1% level.

[14] This is the case for 98.7 percent of my cocaine observations and 98.9 percent of my heroin observations. In unreported results using all observations but omitting price information, similar results are found.

[15] As noted below, I find no impact of U.S. mandatory minimums on the purity of cocaine or heroin in the international data. This indicates that the change in purity is indeed U.S. specific and is therefore unlikely the result of a change in world drug markets.

purities greater than 100 or quantities equal to zero were also deleted. This left 107,747 cocaine observations and 37,972 heroin observations with price data.

Four transaction-specific variables were used: two for prices and two for quantities. Prices were converted into real 2000 dollar values using the personal income price deflator from the Bureau of Economic Analysis (BEA). *Price*, which is the real price per gram, is then used as a control variable.[16] Since the impact of repeat transactions, market uncertainty, and other unobserved factors are likely to be correlated with the price, this variable controls for the influence of such items on purity. In addition, *Total Price*, the real price for the entire transaction was used. The rationale for including this is that large, valuable transactions are likely to be both riskier and resulting from repeated interaction, yielding potentially different effects relative to low-cost transactions even if the price per gram is comparable. Similarly, *Quantity* and *Quantity*^{2} (the square of quantity), both measured in grams, control for the possibility that the retail and wholesale drug markets may have different average purities.[17] The date of the arrest was used to construct eleven month dummies which were used in all specifications but are not reported in the tables.[18]

The legal environment variables are my variables of interest. In order to use a differences-in-differences approach, there are four such variables. The first is a dummy variable *Federal MM* which is equal to 1 for any observation in 1987 or later (the year

[16] Given the criticism of Horowitz (2001), if these prices are biased estimates of actual prices, then this may bias their estimated coefficient. However, since this is not my variable of interest, I am relatively unconcerned with this possibility. As a robustness check, I estimated a specification excluding price as a control. For both cocaine and heroin, the coefficient on mandatory minimums changed little in either magnitude or significance. For more discussion on the possible effects of sample selection in the data, see below.
[17] In unreported results, I used replaced the quantity variables with a set of discrete quantity groups. This had no qualitative and little quantitative impact on the results.
[18] December was the omitted month. Note that these month dummies net out the year-invariant average difference across months and thus do not preclude the use of the year-varying variables discussed below.

the law took effect) and zero otherwise. The second is a dummy variable *Prior State MM* equal to 1 for any observation occurring in a state with its own MM instituted prior to 1987. The third interacts these two thereby providing the difference in the effect of the federal law between states with their own MMs by 1987 and those that did not. Since the introduction of the federal law would likely have a smaller impact in states with their own preexisting MMs, I anticipate a negative coefficient for the interaction of the prior state and federal variables. Note, however, that I do not necessarily expect it to have an equal but opposite coefficient from the federal variable. Since a drug dealer can be arrested and convicted by either federal or local authorities, it is still possible that the introduction of federal MMs on top of state MMs led to an increase in purity. The fourth variable, *Post State MM* is a dummy variable equal to one for any observation occurring in a state with its own MM enacted after the federal law took effect.[19] Similar to the interaction term, I expect that the imposition of a state MM on top of the federal one to have little effect on purity.

These state-level MM variables were created from information collected through communication with state attorney general offices and law enforcement offices. This was then corroborated against the tables listed in the Bureau of Justice Assistance (1996). It is important to note that these state MMs are not always limited to drug offences but that all do indeed apply to drug dealers. A well-known example of this is California's "three strikes" law in which third time felony offenders face a MM.[20] Thus, some states do not have MMs for the initial offense, but do for the second or third offense. In addition some

[19] Note that since all of these state laws are enacted no earlier than 1987, interacting this with *Federal MM* would yield the same variable.
[20] Some states also have mandatory minimums specific for violent offenders (repeat or not). Since this differs significantly from the federal law, I do not count this as a drug offense mandatory minimum.

states had MMs for more specific offenses such as selling drugs within 1,000 feet of a school or for dealers in possession of a handgun. Since these more specific types of laws do not correspond as well to the federal MMs as states' repeat offender laws do, I do not count these. Therefore, the state MM variables indicate the existence of a law under which a repeat, non-violent drug trafficker would face a MM, making this measure of state laws as close a counterpart as possible to the federal law.[21]

In addition, I include a number of additional variables capturing federal and state-specific law enforcement efforts. Access to detailed measurements of these variables is one of the primary reasons drug studies are typically limited to a short time frame or a narrow location. As an alternative, at the national level, I include three measures of activity by the DEA. *Budget* is the DEA's budget measured in real millions of 2000 dollars. *Agents* is the number of special agents employed by the DEA.[22] These data are available on the DEA's website.[23] One possibility is that all of these are positively correlated with purity since they are positively related to the probability of arrest, giving dealers an incentive to further reduce quantity in favor of purity. Alternatively, with more agents, it may be that the DEA is able to target more mid- and low-level dealers, leading to a drop in the average purity. I also include the total number of observations for a given drug (*Total Busts*) in a given year as another proxy of overall effort and effectiveness of law enforcement. At the state level, I include the share of a particular drug's observations

[21] While there is a great deal of variation across states in terms of the number of offenses needed to trigger the mandatory minimum and the severity of the punishment it entails, the complexity and degree of heterogeneity makes it impossible to construct a meaningful variable to exploit these details. Furthermore, several states changed the severity of the sentence imposed and made other legal changes regarding the possibility of parole. Since I am unable to obtain detailed information on the dates of these revisions, I use this simple dummy variable approach.

[22] In unreported results, I also used the total staff of the DEA. This did not greatly impact the results of the variables of interest. However, because of the high correlation between this and *Agents*, it is omitted from the presented results.

[23] At the time of this writing, this was http://www.dea.gov.

in a given state in a given year (*State Intensity*). All else equal (including population), I expect that greater relative interdiction effort in a given location will increase its share of the total observations. Therefore I expect this too to be positively correlated with purity. Finally, as a measure of the overall crime level in a state, I include the FBI's *Crime Index*, which reports the number of crimes in a state-year per 100,000 people.

As well as law enforcement measures, I include a number of state-level economic controls. Economic controls include real gross state product (*GSP*) and real per-capita personal income (*Income*), both from the BEA.[24] I also include the percentage of the population below the poverty line from the Current Population Survey (*Poverty Rate*) and the unemployment rate from the Bureau of Labor Statistics (*Unemployment Rate*). My expectations are that states with high incomes and strong economies will have consumers who demand a higher quality, i.e. a more pure, product. At the same time, however, states with large numbers of poor people may have more users who demand higher purity.

Finally, I include several demographic variables. *Population*, obtained from the BEA, controls for the population of a state. I include three measures of ethnicity: the percentage of blacks aged sixteen and over (*% Black*), the percentage of Hispanics aged sixteen and over (*% Hispanic*), and the percentage of other non-whites aged sixteen and over (*% Other Nonwhite*). Likewise, three age categories were included: *% Aged 0-17*, *% Aged 18-24*, and *% Aged 25-66*. These measure the percentage of the state's population falling into these age categories. Four education categories were included, one for high school graduates (*% High School*), one for some college (*% Some College*), one for four-year college graduates (*% College*), and one for some post-graduate education (*% Post-*

[24] These were converted into real 2000 dollars by respectively using the GDP and personal income price deflators from the BEA.

graduate). All of these measure the percent of the population for whom this is their maximum educational attainment. The percentage of the population that was male (*% Male*) and the percentage of single female-headed households (*% Female Household*) were also included. All of these demographic variables were obtained from the Current Population Survey. Although work cited in Section 2 does consider the impact of demographics on drug demand, this does not necessarily imply specific expectations for the signs of the demographic variables regarding drug purity. However, since I expect frequent drug users to demand a more pure product, I stereotypically expect higher purities in young, uneducated populations with large numbers of minorities and males.

Summary statistics for all of my data are found in Table A1 of the Data Appendix.

4. The Impact of Mandatory Minimums on Purity

Table 4 reports OLS estimates of the impact of MMs.[25] As discussed by Bertrand, Duflo, and Mullainathan (2004), potential serial correlation in errors can yield to false rejections of differences-in-differences estimates. Therefore, as they suggest, errors are clustered by state. The first two columns use the cocaine data and the second two use the heroin data. Columns 1 and 3 use the full sample, whereas columns 2 and 4 use only those observations with quantities less than or equal to one gram. As noted by Horowitz, these amounts are more representative of retail transactions, thus this was done to get a measure of the potential impact at the "street level".[26]

As Table 3 shows, in all four specifications, *Federal MM* is positive and highly significant. For the full sample of cocaine, the estimated coefficient is 25.8. When

[25] In addition to OLS, in unreported estimates I used Tobit due to the presence of purities equal to zero and 100. These results were very similar to those reported.

[26] Using a total transaction price cutoff instead of a quantity cutoff yields similar results.

compared to the average purity of the sample of 62 percent, this implies about a 42 percent increase in purity after the federal MMs took effect. Note that the magnitude of this change is roughly equal to the difference in the average purity just before the law took effect and its high point in 1991. In the "street-level" cocaine sample, the estimated impact is even greater at 30.1 percentage points. Compared to the purity average of 60.8 in this sample, the federal MM increased the purity by about 50 percent. In the heroin data, the magnitude of the federal law's impact is smaller: 8.6 percentage points in the full sample and 6.9 in the "street-level" sample. Given the average purities in these samples of 29.1 and 17.8, this translates to increases of 30 and 39 percent respectively.

As predicted, estimated impact of the federal law is smaller in states that had their own preexisting MMs, although this difference is not significant for the street-level cocaine sample. For the full cocaine sample, this yields a rise from the federal law only about 2/3 the size of that in states without their own MMs. In the heroin data, F-tests indicate that I cannot reject the null hypothesis that the federal law did not affect purity in states with their own MMs. Furthermore, for states that enacted their own MMs after the federal law, purity does not significantly differ from states that never do so. The one exception is in the full cocaine sample, where average purity in these states is actually lower. As with the preexisting state MMs, this may reflect a smaller purity increase from the federal law.

Looking at the estimated impact of the state-level MMs themselves, there is a noticeable difference between the cocaine and heroin data. In the cocaine sample, a preexisting state MM raises the purity (significantly so in the full sample), suggesting that state MMs shifted the market towards higher purities. In the heroin results, however, this coefficient is negative, suggesting the opposite. As the sample statistics of Table 3 indicate, when compared to states without their own MMs, states with preexisting MMs had markedly higher heroin purities both before and after 1987. Since many of the states with preexisting MMs instituted them either before or very early in the sample, it may be that the state-specific fixed effects are washing out much of the impact of these laws in the heroin data, leading to a spurious negative coefficient. In fact, in unreported results omitting state fixed effect, this coefficient becomes insignificant while the other MM variables retain the signs and significance of the reported results.

Turning to the other controls, the coefficients on *Quantity* and $Quantity^2$ indicate that purity is an increasing, concave function of the quantity of the deal. *Agents* and *Budget* are generally negative and significant whereas *Crime Index* and *State Intensity* generally positive and significant. These first two might indicate that when the DEA has greater manpower that it is able to target smaller dealers (arguing against the contention that *Federal MM* is capturing a push by the DEA to target high-purity dealers). This latter is consistent with the notion that high crime regions might attract greater law enforcement, increasing the incentive to shift towards higher purities. The state economic variables generally indicate that higher purities are found in smaller states with higher average incomes but higher incidences of poverty and unemployment. This suggests a possible impact of income inequality on drug markets, a potential subject for future research. Higher purities are also generally found in states with few males, few single female-headed households, greater percentages of minorities (especially Hispanics), and large numbers of teenagers. As for the education variables, greater numbers of graduates at any level is positively correlated with purity, although this is only significant in the full sample suggesting that this is primarily due to a greater number of large transactions (which tend to be purer) in such states.

It is important that comparable results for the federal MM variables are found in both the heroin and cocaine data. Since the time-variation in the purity of powder cocaine may be influenced by the rise of crack cocaine (which is by definition impure but more powerful), then one might be concerned that *Fed MM* is merely reflecting this shift in the cocaine market. This would be the case if crack attracted low-purity users, leaving only high purity, recreational cocaine users. However, it is unclear that the introduction of crack would also attract low-purity heroin users. In addition, one might just as well expect that hardcore users (those who demand higher purity) would be those most attracted to crack. Furthermore, this does not explain why these effects would differ by state according to pre-existing state-level MMs. Unfortunately, the STRIDE database does not provide information on crack and I am unaware of another indicator of crack use that varies by state and year. Thus, while it is possible that the magnitude of the *Fed MM* variable is impacted by an omitted crack effect, it is unclear that the bias is necessarily positive or that the positive coefficient is entirely driven by this omission.

Thus, the data robustly indicate the existence of an effect of federal MMs on the purity of cocaine and heroin. As an additional check on the impact of MMs, I also utilized to the international data available in the STRIDE database. There, I used these data to estimate the effect of U.S. federal MMs on the purity of drugs purchased by the DEA or the FBI in other drug importing countries (i.e. the OECD countries).[27] Since the MMs are only effective for arrests within the United States, their introduction should

[27] The countries used were Australia, Austria, Belgium, France, Germany, Greece, Ireland, Finland, Italy, Korea, the Netherlands, Portugal, Spain, and the United Kingdom.

have no effect on the purity of drugs in other countries. However, if the MM dummy is simply capturing an overall shift in drug markets towards higher purities, then it might well be significantly positive in these international data. As shown in Table 5, after controlling for *Quantity*, *Quantity*^{2}, a common time trend, and country fixed effects, *Federal MM* is insignificant in the cocaine and significantly negative in the heroin regressions.[28] This adds further evidence that this federal MM variable is capturing something other than a simple positive change in the trend of drug purity. In the next section, I explore one potential impact from this increase in purity.

5. Purity and Emergency Room Episodes

While recognition of the effect of MMs on purity is interesting in its own right, it is worth asking what impacts this may have had. One effect, as noted by the DEA (1999), is that readily available, highly-pure heroin is attracting users unwilling to inject it. According the Substance Abuse and Mental Health Services Administration (2004), between 1992 and 2003 the number of users inhaling heroin increased from 20 percent to 33 percent while the number injecting it decreased from 77 percent to 62 percent. In addition, higher purities may make it more difficult to break addiction.

Another potential result from the shift in purity concerns the need for users to seek medical attention. As Figures 2 and 3 show, for the U.S. as a whole the number of emergency room episodes (ER mentions) that mentioned cocaine or heroin use rose markedly during the 1990s. [29] At the same time, the average purity of cocaine fell while

[28] Due to the scarcity of price information in these data, I exclude them as explanatory variables to boost sample size.
[29] Figures 2 and 3 use only observations of one gram or less to calculate the average and standard deviation of purity.

that of heroin rose (although both were significantly higher than they were before 1987). Thus, at least the heroin numbers might suggest that higher average purity levels increase ER mentions. This begs the question of why drug users do not simply reduce the amount that they consume as purities rise. One possibility, as discussed by Bernheim and Rangel (2004), is that they do not behave like forward-thinking rational economic agents, but enter a "hot state" in which they consume as high a quantity as possible. Nevertheless, one would imagine that such users would alter the quantity they keep on hand to adjust to changes in average purity. An alternative is that some other, uncontrolled-for factor has risen along with average purity and ER mentions.

One such candidate is the variance in purity within a location during a given period of time. As Table 1 indicates, the MM for a repeat offender is twice that of a comparable first-time offender. As such, one would expect repeat offenders to shift more towards purity in response to the MM.[30] In addition, variation in dealers' understanding of the law might lead to differing levels of response to MMs. Both of these would lead to heterogeneous purity changes in response to the ADAA. Added to this is the fact that some offenders are permitted to trade information for reduced sentences. Since access to information varies across dealers, their need to increase purity might as well. Furthermore, as more dealers are apprehended and become repeat offenders, these response differences may well grow over time. Finally, the ADAA may have led to a decentralization of the drug dilution process. All of these would contribute to heterogeneous dealer responses to the MMs. As a result, the rise in purity would vary across dealers, leading to potential increases in the variance of purity. As Figures 2 and 3

[30] Unfortunately, data on the offender is not available from the STRIDE database therefore I cannot examine how the response might vary with offender-specific characteristics.

show, the standard deviation of cocaine and heroin purity did indeed rise following the imposition of federal MMs. Figure 4 presents this information in a different way, illustrating histograms for the purity of observations under one kilo before and after federal MMs. For both cocaine and heroin, after 1987 there is a noticeable shift towards higher purities. Furthermore, there is a clear increase in the dispersion of purity. Thus, again the data indicate that the variance of purity rose following the introduction of federal MMs.[31]

This greater uncertainty regarding purity may then lead to more accidental over-consumption and more ER mentions even if users cut back on the quantity consumed due to higher average purity. As described by the National Institute on Drug Abuse (2004b), the wide variation in street-level heroin purity is a primary reason for heroin overdoses. Therefore, if agents are economically rational, it may not be the average purity that matters for ER mentions, but the standard deviation in purities.

To test this possibility, I utilize the DAWN's dataset on emergency room mentions for cocaine and heroin. This dataset reports the number of ER mentions per 100,000 for the 21 Metropolitan Statistical Areas (MSAs) listed in table A2 of the Data Appendix. The time period used is 1990 to 2001.[32] These data were used by Caulkins (2001), Hyatt and Rhodes (1995), and Dave (2004) to estimate the effect of drug prices on mentions. Following these studies, I use a reduced form specification where the number of ER mentions for drug d in MSA m in year t is:

$$ER_{d,m,t} = \alpha_0 + \alpha_1 Avg.price_{d,m,t} + \alpha_2 X_{m,t} + \alpha_3 PureVars_{d,m,t} + \alpha_4 Trend_t + \varepsilon_{d,m,t}$$

[31] Note that I am not claiming that mandatory minimums caused these changes. I address this possibility in Section 6.
[32] The response rate data were graciously provided by Dhaval Dave. Note that due to some missing observations, I am left with an unbalanced panel.

Where $Avg.price_{d,m,t}$ is the average price per pure gram of the drug, $X_{m,t}$ are other MSA-specific controls, $PureVars_{d,m,t}$ is a vector of purity variables for the drug in question, $Trend_t$ is a linear trend, and $\varepsilon_{d,m,t}$ is the error term. As in the above studies, MSA controls include the percentage of an MSA's hospitals responding to the DAWN survey (*Response Rate*), a time trend, and real income of the MSA.[33] Unlike those studies, in some specifications I also control for the average purity, the standard deviation of purity, and the skewness of purity for a given MSA in a given year. The average price and the three purity variables were all constructed using observations with quantities less than one gram.[34] Summary statistics for the data used in these regressions are in Table A3 of the Data Appendix. This specification is estimated separately for cocaine and heroin.

Table 6 presents the results for total cocaine ER mentions. Column 1 presents a baseline specification that is comparable to the existing literature, including only the average price of cocaine, a trend, real income, and the response rate. As in earlier studies, I find a negative and significant coefficient for the average price. This would be consistent with higher prices reducing use and therefore the need for medical attention. Column 2 adds the average purity to this baseline specification. As can be seen, the average purity of cocaine appears to be negatively related to the number of ER mentions. However, as Column 3 shows, this is due to an omitted variable bias. Column 3 also adds the standard deviation and the skewness of cocaine purity. Of these, only the standard deviation is significant. Consistent with the above discussion, it is positive, suggesting

[33] In unreported results using the average actual price per gram (uncorrected for purity), comparable results were found for the distribution of purity coefficients.
[34] This differs from Dave (2004) who uses observations of 40 grams or less. I use this smaller amount due to Horowitz's (2001) observation that most retail sales involve smaller amounts of around one gram. Also, due to missing data for some MSA's, rather than use Dave's approach of substituting statewide data, I drop this MSA-year. If such replacements are made, similar results are obtained.

that greater uncertainty increases ER mentions. To give an idea of the magnitude of these changes, between 1986 and 1987, the standard deviation of cocaine purity rose by 4.4 percentage points. This translates to 772 more cocaine ER mentions per 100,000. Comparing this to the sample mean, this is an increase of 15 percent. Note that when including the standard deviation of purity, the average purity becomes insignificant while the average price retains its standard, significantly negative coefficient.

Column 4 modifies the above specification by adding the average price, the average purity, and the standard deviation of purity for heroin as explanatory variables for cocaine ER mentions. As in Column 3, the cocaine standard deviation is positive and significant. In addition, the standard deviation of heroin is positive and significant. This suggests three possibilities. First, greater uncertainty in the heroin market, all else equal, leads more consumers to use cocaine, increasing cocaine ER mentions. Second, it could be that the heroin standard deviation acts as another proxy for overall drug market uncertainty. Third, this might be the result of an increased risk from joint usage, leading to more ER mentions for either drug. Finally, Column 5 repeats the specification of Column 4 but also controls for MSA fixed effects. Here, the standard deviation of heroin purity is again positively correlated with cocaine ER mentions.

Table 7 undertakes a comparable set of regressions for heroin ER mentions. As in the cocaine results, I find the typical result that a higher average price is significantly related to fewer heroin ER mentions. Also like the cocaine data, I find a significant effect from the average heroin purity only when I omit the standard deviation of heroin purity. The only robustly significant coefficient is that for the standard deviation of heroin purity. Using the estimated coefficient of 94.3, this suggests that the four percentage point increase in the standard deviation of heroin purity following federal MMs would be associated with an increase in heroin ER mentions of 377 per 100,000 people. Relative to the mean in the sample, this is a 15.4 percent increase. This result is robust to the inclusion of MSA fixed effects, as shown in Column 5. Also noteworthy is that, at least when not using MSA fixed effects, the standard deviation of cocaine purity is also positively correlated with heroin ER mentions, which is again suggestive of risk substitution between drugs.

Finally, Table 8 uses additional data from the DAWN that describe the outcome of the ER mentions as well as the reason the patient sought help, assuming that these were known. These more detailed data are available only for 1995 to 2001.[35] To my knowledge, these data have yet to be used by economists. I report the results for three items: deaths per 100,000, overdoses per 100,000, and the number of complaints of unexpected reaction per 100,000. All of these are used separately for cocaine and heroin mentions. In all specifications, in addition to the MSA controls used above I include the average price, the average purity, and the standard deviation of purity of the drug in question. Since cross-drug effects and skewness were rarely significant in these results, they are omitted from the reported results. When included, they did not greatly impact the reported coefficients.

Across the specifications, higher prices are usually associated with fewer negative outcomes possibly due to less use. However this effect is never significant. The standard deviation of purity, on the other hand, is almost always positive and significant. Greater uncertainty over cocaine purity is significantly and positively correlated with all three

[35] When controlling for MSA fixed effects, coefficients from these specifications were rarely significant. This is likely due to the shorter time series for which these detailed outcomes are available.

outcomes. Given the change in standard deviation at the time of the ADAA, these estimates translate to around one more death, 57 more overdoses, and 145 more unexpected reactions per 100,000. Relative to the respective sample means, these correspond increases of 9 percent, 14.1 percent, and 13.1 percent.

For heroin, neither the average nor the variance of heroin purity are significantly correlated with deaths. One potential explanation for this difference between heroin and cocaine deaths is that long-term cocaine users become more sensitive to the drug's anesthetic and convulsant effects which are linked to the primary causes of death from cocaine use (NIDA, 2004a). Heroin users, however, do not exhibit an increased probability of death after continued use.[36] Like the cocaine results, however, the standard deviation of heroin purity is positively linked to both overdoses and unexpected reactions. Using the increase in standard deviation following the ADAA, these coefficients translate to 44 more overdoses and 30 more unexpected reactions per 100,000. Again, compared to the sample means, these imply increases of 9.6 percent and 9.7 percent respectively. Finally, the only time that average purity is significant in Table 8 is for unexpected reactions from heroin use. Here, it is negative and significant. This suggests that higher average purity seemingly reduces the number of unexpected heroin reactions, potentially due to fewer unexpected adulterating substances. As an indicator of the magnitude of this effect, the 12.8 percentage point increase in average heroin purity due to MMs would correspond to a drop in heroin unexpected reactions of 86 per 100,000, a reduction of 28.1 percent relative to the sample mean.

[36] In conversations with emergency room medical staff, I was informed that their rule of thumb is that a death by heroin overdose is a suicide since it is so difficult to accidentally die of a heroin overdose.

Taken together, these results suggest that higher average purities of cocaine and heroin are not associated with a rise in emergency room mentions, but that increased variance may well be. Thus, if MMs did indeed lead to higher average purities and higher variances around that mean, then yet another unintended effect of the ADAA of 1986 may have been to increase the number of health emergencies associated with drug use. In particular, since many drug users are likely uninsured, this poses a substantial cost to the general public. According to the Robert Wood Johnson Foundation (2001), nearly 20% of all Medicaid hospital costs and nearly 25% of its inpatient care costs are the result of substance abuse. To give an idea about the magnitude of this cost, according to Nordlund, Mancuso, and Felver (2004), the average cost of an ER visit from a drug overdose in Washington state during 2002 was $1,456. Using the numbers from Tables 6 and 7, where the change between 1986 and 1987 implies 1149 more ER mentions from cocaine or heroin per 100,000, for Seattle's MSA population of 2.4 million, this would translate into a cost of just over $40 million per year for that city alone. These costs are in addition to the other health and productivity losses resulting from drug use, costs which the Office of National Drug Control Policy (2001) put at $161 billion in 2000.

6. The Impact of Mandatory Minimums on the Standard Deviation of Purity

While the data does show that the standard deviation of cocaine and heroin purity rose following the introduction of federal MMs, this does not guarantee a significant link between the two. Furthermore, given the discussion above, the ADAA may well have had conflicting effects on the standard deviation of purity. As such, the net effect is uncertain and must be determined empirically. Therefore in this section I employ a methodology similar to that used in Section 4 to ask whether such a significant link exists and whether its magnitude differs between states that had their own MMs and those that did not.

To do this, I use the STRIDE data described in Section 3 to construct the standard deviation of purity in a state within a given year. When there was only one observation for a given drug in a given state-year, this observation was dropped. Consistent with the approach in Section 5, I construct this measure using only those observations where the quantity is less than or equal to one gram. In addition to the standard deviation of purity, five other variables were constructed: the average purity, the skewness of purity, the average price per gram, the average price per transaction, and the average quantity per transaction. The other controls used are the same as those in Tables 2 and 3. Note that these include state fixed effects and state-specific time trends.[37] Again, errors are clustered by state.

The results from these regressions appear in Table 9, where Column 1 reports the cocaine estimates and Column 2 reports the heroin estimates. As Column 1 shows, the estimated impact of federal MMs on the standard deviation of cocaine purity is 6 percentage points with no significant difference between states with their own MMs and those without. Given the estimates from Column 4 of Table 6, this suggests that in a state without its own MM, the ADAA would be associated with a 28 percent rise in cocaine ER mentions. Turning to the heroin results, the estimates suggest that federal MMs had no effect. However, the institution of a state MM prior to 1987 it increased the standard deviation by 4.4 percentage points. Using the estimates from Column 4 of Table 7, a preexisting state MM would be associated with a 21 percent rise in heroin ER mentions in these states. Unfortunately, I do not have data on ER mentions from the period

[37] Because of the switch to annual, state-level observations I am unable to use month dummies.

surrounding the ADAA to compare to these predictions to the actual change. Nevertheless, these estimates suggest that the ADAA may well have impacted the health consequences of drug use even if drug users respond to anticipated changes in purity.

7. Conclusion

The goals of this paper have been threefold. First, it estimated the impact of federal MM sentences that are based on gross quantity on the purity of cocaine and heroin. For a variety of specifications, the data indicates that there was a significant rise in drug purity following the Anti-Drug Abuse Act. Unlike many studies on illegal drug markets, my goal has not been to estimate the effect of this policy on the price of drugs or on usage. Caulkins, Rydell, Schwabe, and Chiesa (1997) perform such an analysis and find that a million dollars spent on federal MM sentences yields a reduction in cocaine consumption of less than 40 kilos (compared to the 100 plus kilo reduction from equal spending on treatment of heavy users). One of the primary reasons I did not take the typical approach is that, since prices are not the key variable, my estimates are insulated from the criticism of Horowitz (2001) regarding the prices negotiated by DEA agents. Second, in addition to documenting the effect of MMs, I consider how average purity and the distribution of purity affect emergency room episodes. In particular, I find that the standard deviation of purity seems to be a primary determinant of negative health consequences, including total emergency room visits, overdoses, and death. Third, I find that the introduction of federal MMs played a role in the uncertainty over cocaine purity, providing a link between the ADAA and drug-related emergency room episodes.

In closing, it is worth considering what policy implications can be drawn from these results. With regards to heroin, higher purities appear to have increased in the number of heroin users because of the decreased need to inject the drug. In addition, the purity of heroin rose with no change in the standard deviation. This suggests a reduction in the likelihood of an unexpected reaction from use. Combined, these results suggest that federal MMs may increase heroin use by reducing some of its negative consequences (although this may be offset by some state laws). At the same time, however, the stiffer penalties likely increased the price and thereby reduce consumption. For cocaine, the reductions in consumption due to price increases are bolstered by a rise in the standard deviation of purity and the associated increase in the risk of negative health effects. Thus, if the government's objective is to reduce the number of users, the net effectiveness of such laws is uncertain. Alternatively, if the goal is to reduce the risk borne by addicts, sentencing structures that do not induce heterogeneous producer responses may reduce emergency room mentions.

One final point is to note that this paper focuses on the impact of federal MMs. Beyond this policy, there are a variety of federal and local enforcement measures that I do not directly consider. In addition, I only consider the cocaine and heroin markets. Finally, it is likely that purity changes have impacted other outcomes from drug use besides emergency room mentions. Given the large expenditures on interdiction, incarceration, and dealing with the impacts of drug use, these topics clearly warrant further attention by researchers.

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Table 1. Federal Mandatory Drug Sentences for First-time Offenders

Type of Drug		Sentence for First Offense	Sentence for Second Offense
Powder Cocaine	500 grams	5 years	10 years
	5 kilos	10 years	20 years
Crack Cocaine	5 grams	5 years	10 years
	50 grams	10 years	20 years
Heroin	100 grams	5 years	10 years
	1 kilo	10 years	20 years
LSD	1 gram	5 years	10 years
	10 grams	10 years	20 years
Marijuana	100 plants or 100 kilos	5 years	10 years
	1000 plants or 1000 kilos	10 years	20 years
Methamphetamine	5 grams	5 years	10 years
	50 grams	10 years	20 years
PCP	10 grams	5 years	10 years
	100 grams	10 years	20 years

Source: Anti-Drug Abuse Act (1986).

Table 2: State Mandatory Minimums for Repeat Drug Offenders

Alabama	1977		Nebraska	1977
Alaska	1982		Nevada	1971
Arizona	1978		New Hampshire	1969
Arkansas	1971		New Jersey	1987
California	1977		New Mexico	----
Colorado	1992		New York	1973
Connecticut	----		North Carolina	1994
Delaware	1987		North Dakota	1993
Florida	1973		Ohio	1996
Georgia	1994		Oklahoma	1982
Hawaii	1976		Oregon	----
Idaho	1990		Pennsylvania	1988
Illinois	2004		Rhode Island	1988
Indiana	1976		South Carolina	1976
Iowa	1979		South Dakota	1989
Kansas	----		Tennessee	1989
Kentucky	----		Texas	1974
Louisiana	----		Utah	----
Maine	1988		Vermont	----
Maryland	2002		Virginia	1992
Massachusetts	1987		Washington	----
Michigan	1978		Washington, D. C.	----
Minnesota	1989		West Virginia	1971
Mississippi	1977		Wisconsin	----
Missouri	1989		Wyoming	1982
Montana	1993			

Table 3: Average Purities for Observations Under 1 Gram

	Cocaine		**Heroin**	
	Prior to 1987	**After 1987**	**Prior to 1987**	**After 1987**
State mandatory minimum instituted prior to 1987	**26.9**	**36.0**	**14.3**	**27.9**
No state mandatory minimum	**22.9**	**53.2**	**6.5**	**19.0**
State mandatory minimum instituted after 1987		**33.5**		**36.5**

Table 4: Effect of Mandatory Minimums on Purity

	(1)	(2)	(3)	(4)
	Cocaine		Heroin	
	All Quantities	≤ 1 Gram	All Quantities	≤ 1 Gram
Federal MMM	25.766*** (7.98)	30.147*** (7.01)	8.555*** (3.24)	6.931*** (2.65)
Prior State MM	9.134*** (2.84)	12.154 (1.32)	-6.144*** (3.27)	-7.283*** (4.04)
Prior State MM *Federal MM	-7.153* (1.83)	-7.929 (0.77)	-7.212** (2.38)	-8.070** (2.05)
Post State MM	-4.831** (2.06)	-0.407 (0.09)	4.831 (1.49)	8.098 (1.31)
Other controls:				
Price	3.6e-5 (1.54)	-0.001* (1.69)	2.5e-4*** (4.36)	8.7e-5 (0.36)
Total Price	-1.0e-10* (1.73)	0.003 (1.57)	-1.1e-7*** (3.84)	2.4e-4 (0.53)
Quantity	6.6e-5 (1.22)	74.921*** (3.41)	0.011*** (5.44)	48.569*** (3.56)
Quantity^2	-1.0e-12 (0.02)	-56.691*** (4.60)	-1.3e-7*** (4.02)	-32.860*** (3.05)
Agents	-0.013*** (5.11)	-0.011*** (2.66)	-0.007*** (3.52)	-0.008*** (2.87)
Budget	-0.005 (1.02)	-0.016*** (2.82)	-0.006** (2.22)	3.2e-5 (0.01)
Crime Index	1.3e-5 (1.27)	1.9e-5* (1.75)	1.1e-5** (2.05)	1.2e-5** (2.47)
Total Busts	0.002*** (2.63)	0.003*** (6.33)	0.001 (0.29)	-0.009*** (3.33)
State Intensity	39.221* (1.92)	25.981 (1.09)	5.465 (0.29)	37.014** (2.16)
Population	-6.3e-6 (1.12)	-7.7e-6 (1.00)	-2.4e-6 (0.89)	-6.2e-6** (2.18)
GSP	-9.0e-5*** (3.61)	-1.2e-4** (2.44)	-7.9e-6 (0.26)	2.2e-5 (0.76)
Income	0.002*** (2.71)	0.001 (1.29)	0.002** (2.38)	0.001 (0.78)
Poverty Rate	0.750** (2.25)	-0.484 (1.17)	-0.025 (0.11)	-0.139 (0.46)
Unemployment Rate	0.040 (0.11)	0.084 (0.17)	0.842** (2.32)	1.136** (2.47)
% Male	-1.993*** (3.16)	-2.015*** (3.44)	0.533 (1.00)	0.846 (1.50)

% Female H-hold	-0.919*** (4.32)	-0.956** (2.34)	-0.250 (1.16)	-0.304* (1.66)
% Hispanic	0.914** (2.06)	2.194*** (3.09)	1.040** (1.99)	1.447** (2.09)
% Black	-0.220 (0.51)	-0.632 (1.07)	0.278 (0.92)	0.611* (1.88)
% Other Nonwhite	0.280 (0.67)	0.880 (0.82)	1.015* (1.87)	1.390** (1.96)
% Aged 0-17	1.901*** (4.86)	1.823** (2.10)	0.607 (0.92)	-0.727 (1.12)
% Aged 18-24	0.809 (1.12)	0.254 (0.25)	-1.539* (1.85)	-1.918* (1.89)
% Aged 25-66	1.726*** (3.58)	1.148* (1.70)	-0.190 (0.35)	-0.110 (0.12)
% High School	1.462*** (2.64)	0.907 (1.08)	1.037** (2.29)	-0.023 (0.04)
% Some College	1.173** (2.26)	0.474 (0.58)	1.614*** (3.68)	0.829 (1.36)
% College	1.156** (2.05)	0.773 (0.93)	2.411*** (6.35)	1.263** (2.02)
% Post-graduate	1.474* (1.85)	1.300 (1.12)	1.481* (1.81)	0.315 (0.36)
Constant	-34.156 (0.60)	44.423 (0.50)	-95.544 (1.44)	-3.026 (0.04)
Observations R-squared	107747 0.17	24406 0.25	37972 0.43	15207 0.42
H_0: Federal MM + Prior State MM* Fed. MM = 0	28.7***	5.53**	.35	.17
H_0: Prior State MM = Post State MM	13.22***	1.43	7.55***	4.65**

All specifications include state-specific quadratic trends, month dummies, and state fixed effects. T-statistics in parentheses. Errors are corrected for clustering on states.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 5: U.S. Mandatory Minimums and International Observations

	(1) Cocaine	(2) Heroin
Federal MM	**-1.258**	**-17.223*****
	(0.66)	**(7.21)**
Quantity	0.000	0.000***
	(1.02)	(4.74)
$Quantity^2$	-0.000	-0.000***
	(1.04)	(4.30)
Trend	0.001	0.445***
	(0.01)	(2.66)
Constant	78.250	-828.943**
	(0.23)	(2.50)
Observations	1071	1744
R-squared	0.07	0.08

All specifications include country fixed effects. T-statistics in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 6: Total Cocaine Emergency Room Mentions

	(1)	(2)	(3)	(4)	(5)
Avg. Cocaine Price	-0.348***	-0.377***	-0.204**	0.010	0.018
	(4.07)	(3.93)	(2.20)	(0.11)	(0.25)
Avg. Cocaine Purity		-26.260*	16.621	45.491	31.109
		(1.66)	(0.41)	(0.79)	(1.41)
Std. Dev. of Cocaine Purity			175.463***	244.245***	32.915
			(3.22)	(3.55)	(1.43)
Skewness of Cocaine Purity			634.310	779.909	560.803
			(0.89)	(0.77)	(1.50)
Avg. Heroin Price				70.754	9.054
				(0.94)	(0.34)
Avg. Heroin Purity				-34.733	-3.496
				(1.10)	(0.22)
Std. Dev. of Heroin Purity				191.029***	25.637*
				(3.82)	(1.76)
Other controls:					
Trend	-38.361	-67.928	76.198	-160.876	370.996***
	(0.30)	(0.52)	(0.60)	(1.09)	(3.12)
Real Income	0.141*	0.155*	0.170*	0.408***	-0.254
	(1.83)	(1.90)	(1.81)	(3.63)	(1.48)
Response Rate	3.475	7.950	0.699	-9.139	-31.985
	(0.10)	(0.21)	(0.02)	(0.24)	(0.87)
Constant	77,255	136,502	-158,886	300,720	-727,304***
	(0.31)	(0.53)	(0.63)	(1.03)	(3.10)
Observations	166	166	166	136	136
R-squared	0.04	0.05	0.11	0.35	0.93
					MSA Fixed Effects

Robust t statistics in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 7: Total Heroin Emergency Room Mentions

	(1)	(2)	(3)	(4)	(5)
Average Heroin Price	-0.029**	-0.027*	-0.039**	-0.024	-0.004
	(2.03)	(1.97)	(2.40)	(1.15)	(0.21)
Average Heroin Purity		17.307*	0.357	-3.529	-6.997
		(1.72)	(0.03)	(0.20)	(0.61)
Std. Dev. of Heroin Purity			94.302***	117.687***	22.841**
			(5.00)	(4.84)	(2.24)
Skewness of Heroin Purity			166.404	289.077	66.490
			(0.80)	(0.97)	(0.30)
Avg. Cocaine Price				149.571	65.107
				(1.40)	(1.50)
Avg. Cocaine Purity				6.271	8.057
				(0.57)	(1.17)
Std. Dev. of Cocaine Purity				114.147***	18.809
				(4.44)	(1.50)
Other controls:					
Trend	-31.162	-50.089	-84.214	-21.454	308.886**
	(0.65)	(0.96)	(1.61)	(0.31)	(2.33)
Real Income	0.290***	0.294***	0.260***	0.296***	-0.167
	(7.24)	(7.42)	(6.50)	(5.73)	(0.86)
Response Rate	11.307	8.770	6.660	-19.208	-11.179
	(0.64)	(0.49)	(0.37)	(0.86)	(0.35)
Constant	55,053	92,381	159,818	31,049	-608,958**
	(0.58)	(0.89)	(1.54)	(0.22)	(2.34)
Observations	179	179	174	136	136
R-squared	0.23	0.24	0.35	0.48	0.89
					MSA Fixed Effects

Robust t statistics in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 8: Effect of purity distribution on detailed outcomes

	Cocaine			Heroin		
	(1)	(2)	(3)	(4)	(5)	(6)
	Death	Overdose	Unexpected Reaction	Death	Overdose	Unexpected Reaction
Average Price	-0.003	-0.323	-1.301	-0.001	-0.020	0.044
	(0.27)	(0.60)	(0.76)	(0.79)	(0.64)	(0.54)
Average Purity	-0.026	-3.193	-8.403	-0.036	0.518	-6.752**
	(0.59)	(1.20)	(1.20)	(0.52)	(0.29)	(2.17)
Std. Dev. of Purity	0.191**	13.007**	32.997*	0.129	10.957***	7.507**
	(2.38)	(2.25)	(1.90)	(1.45)	(3.53)	(2.36)
Other controls:						
Trend	-0.767	-22.575	17.548	-0.121	-20.169	6.049
	(1.36)	(0.68)	(0.20)	(0.15)	(0.89)	(0.17)
Real Income	0.000	0.017	0.037	0.000	0.046***	0.023***
	(0.56)	(1.65)	(1.53)	(1.55)	(6.77)	(3.09)
Response Rate	0.039	-9.462*	-20.605	0.081	-0.044	-1.190
	(0.41)	(1.66)	(1.22)	(0.73)	(0.01)	(0.21)
Constant	1,528.750	45,708.514	-34,045.887	231.467	39,013.520	-12,415.977
	(1.36)	(0.70)	(0.19)	(0.15)	(0.87)	(0.18)
Observations	76	99	99	79	97	96
R-squared	0.11	0.12	0.09	0.07	0.40	0.12

Robust t statistics in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%.

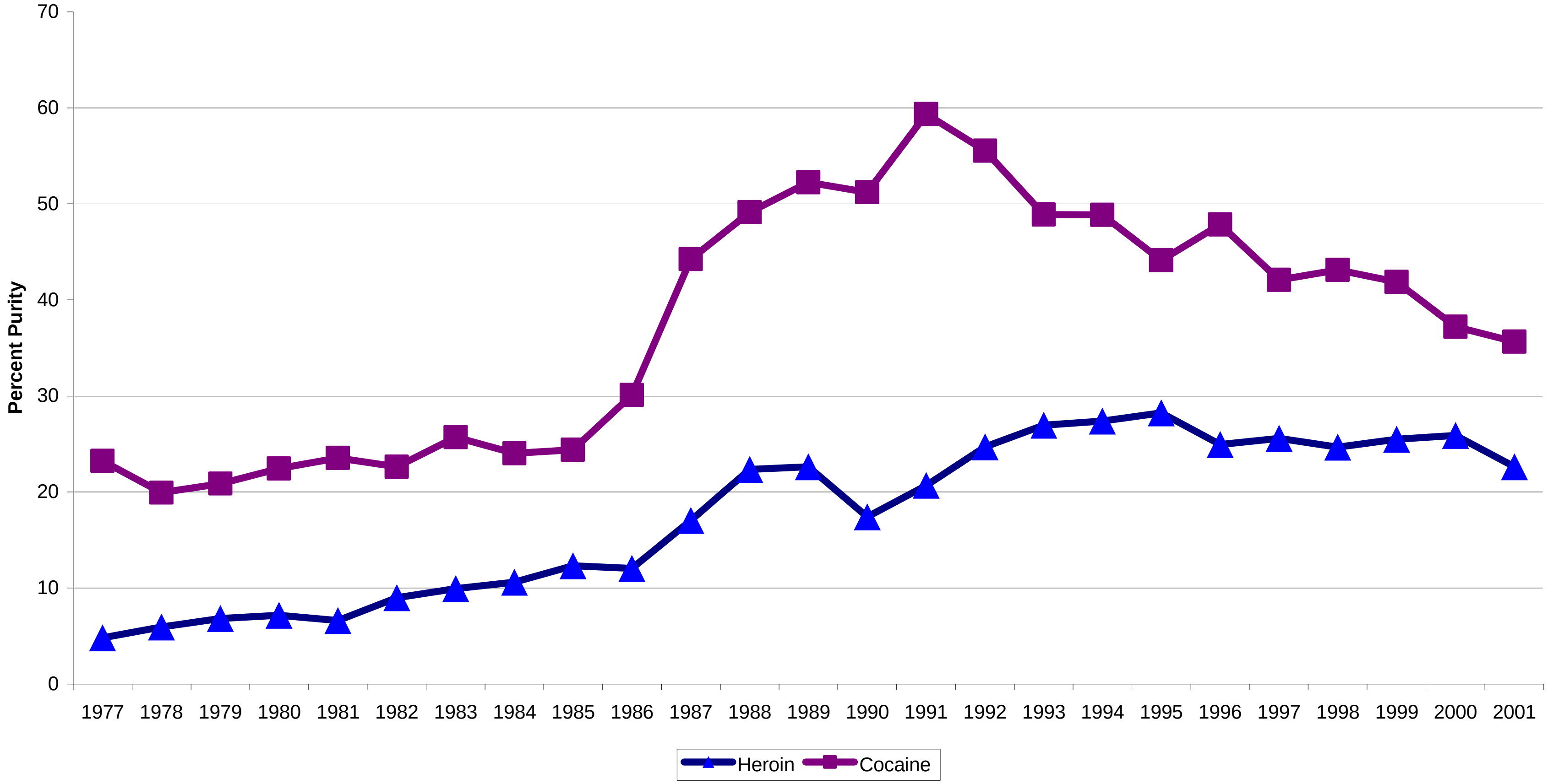
Table 9: The Effect of Mandatory Minimums on the Standard Deviation of Purity

	(1) Cocaine	(2) Heroin
Federal MM	5.915***	-2.127
	(4.15)	(1.23)
Prior State MM	3.805	4.437**
	(1.29)	(2.48)
Prior State MM *Federal MM	-0.736	0.629
	(0.40)	(0.21)
Post State MM	-0.501	-2.741
	(0.33)	(1.09)
Other controls:		
Avg. Purity	-0.139	0.395***
	(1.27)	(4.12)
Skew of Purity	-5.734***	2.255***
	(3.24)	(4.13)
Avg. Price	-0.002	0.002***
	(1.51)	(5.26)
Avg. Total Price	0.002	-0.002*
	(1.63)	(1.77)
Avg. Quantity	1.254	-1.044
	(0.11)	(0.09)
Avg. Quantity^2	-23.201	-8.640
	(1.38)	(0.69)
Agents	-0.005***	-0.004**
	(3.09)	(2.16)
Budget	0.003	0.002
	(0.89)	(0.73)
Crime Index	0.000	0.000
	(1.56)	(1.33)
Total Busts	0.002***	-0.003*
	(3.69)	(1.73)
State Intensity	-32.916***	-8.798
	(2.96)	(0.63)
Population	-0.000	-0.000
	(1.54)	(0.75)
GSP	-0.000	-0.000
	(0.54)	(0.04)
Income	0.000	-0.000
	(0.30)	(0.42)
Poverty Rate	0.136	-0.130
	(1.17)	(0.57)
Unemployment Rate	-0.066	0.377
	(0.28)	(1.01)

% Male	-0.586* (1.76)	0.202 (0.41)
% Female Household	-0.017 (0.13)	0.077 (0.43)
% Hispanic	-0.420* (1.86)	0.164 (0.47)
% Black	0.130 (0.57)	-0.113 (0.38)
% Other Nonwhite	0.071 (0.28)	0.491 (1.61)
% Aged 0-17	-0.180 (0.52)	0.241 (0.47)
% Aged 18-24	0.072 (0.13)	0.650 (1.11)
% Aged 25-66	0.209 (0.58)	0.758* (1.94)
% High School	0.099 (0.33)	0.000 (0.00)
% Some College	-0.361 (1.32)	-0.281 (0.57)
% College	-0.306 (1.14)	-0.105 (0.24)
% Post-graduate	-0.302 (0.78)	0.193 (0.30)
Constant	97.810** (2.14)	-38.021 (0.79)
Observations	829	655
R-squared	0.56	0.71
H_0: Prior State MM After 1987 = Post State MM After 1987		

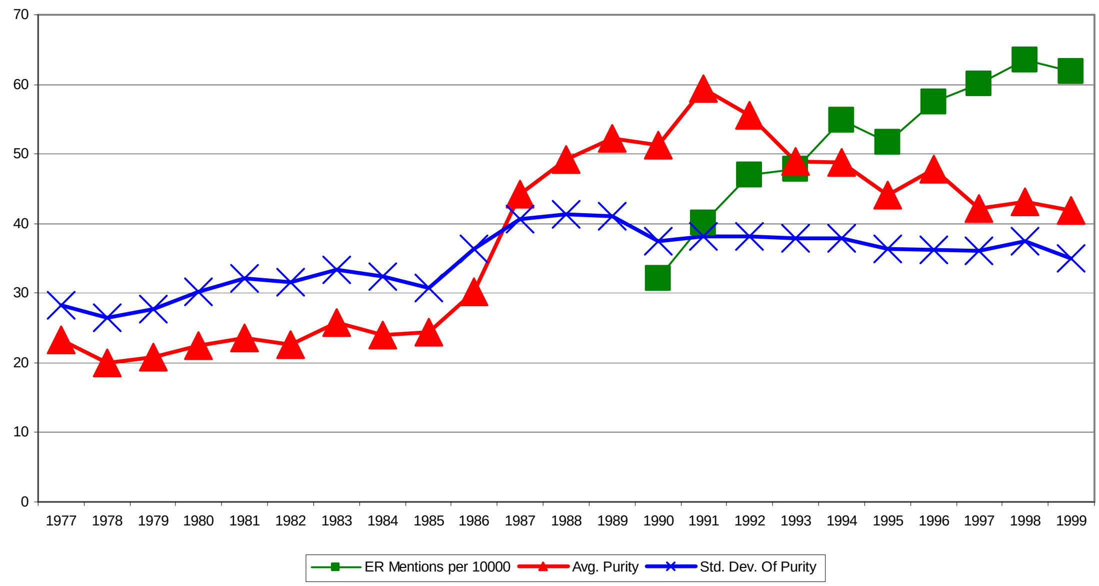
All specifications include state-specific time trends and state fixed effects. T-statistics in parentheses. Errors are corrected for clustering on states.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Figure 1: Average Purity for Seizures One Gram or Less



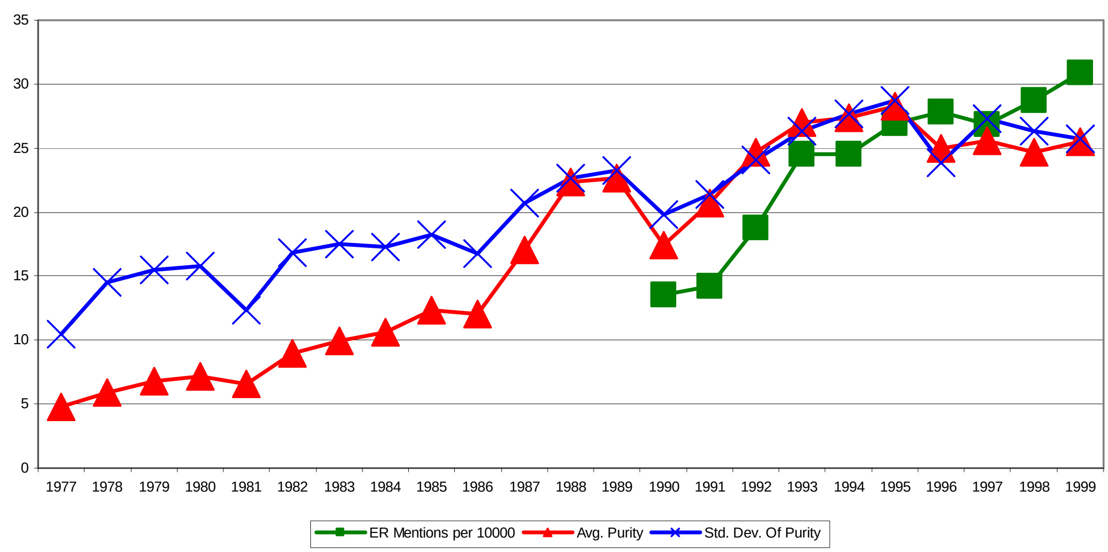
Source: STRIDE.

Figure 2: Cocaine Purity and ER Mentions



Sources: DAWN and STRIDE.

Figure 3: Heroin Purity and ER Mentions

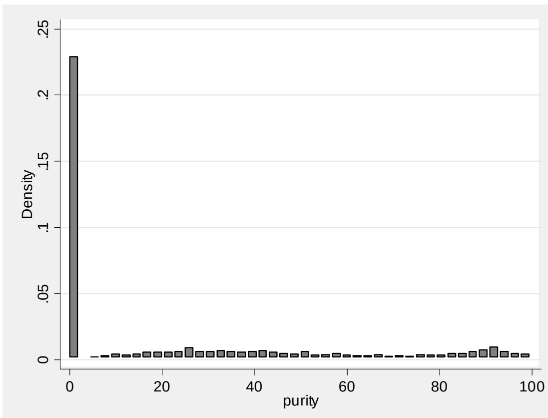


Sources: DAWN and STRIDE.

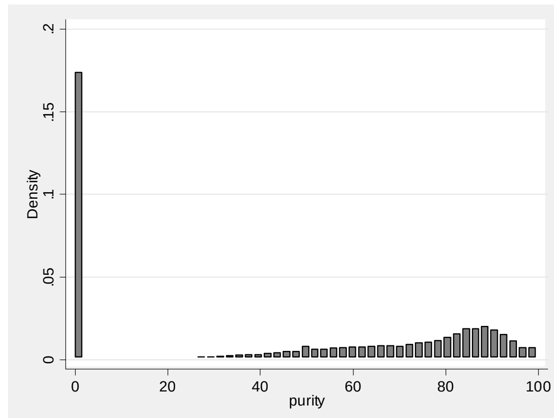
Figure 4: Distribution of Purity for Observations Under One Gram

Cocaine

1977-1986

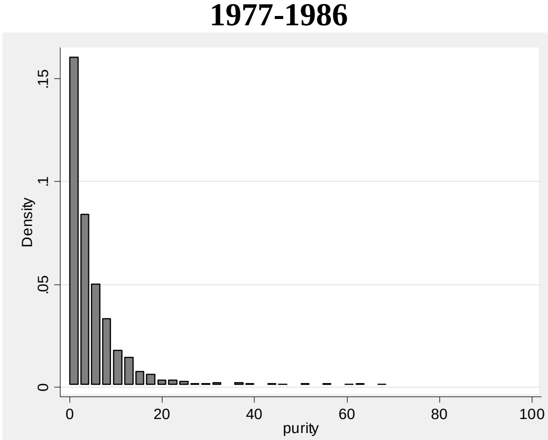


1987-2001

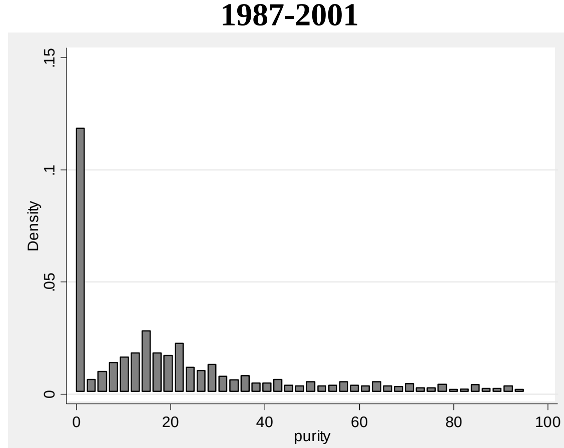


Heroin

1977-1986



1987-2001



Source: STRIDE.

Data Appendix

Table A1: Summary Statistics for Mandatory Minimum Data

Variable	Obs.	Mean	Std. Dev.	Minimum	Maximum	Source
Cocaine						
Quantity	107747	88.08726	5190.252	.0001	1079470	STRIDE
Purity	107747	62.63515	25.05883	0	100	STRIDE
Total Price	107747	2041.234	32457.96	0	6988654	STRIDE
Total Busts	107747	1233.978	1594.143	1	7213	STRIDE
State Intensity	107747	.0762997	.0934419	.0000576	.3628664	STRIDE
Heroin						
Total Busts	107747	334.138	426.1965	0	2056	STRIDE
Quantity	37972	25.86766	323.0952	.0001	50010	STRIDE
Purity	37972	29.09451	28.433	0	100	STRIDE
Total Price	37972	3081.696	17716.4	0	2393647	STRIDE
State Intensity	107747	.0767003	.095416	0	.4488623	STRIDE
State Controls						
Population	107747	7492379	7405307	397363	3.45e+07	BEA
GSP	107747	231872.2	240208.8	7865.195	1330025	BEA
Income	107747	26274.85	5330.126	13587.31	41530.2	BEA
Staff	107747	6968.145	1584.127	4013	9209	DEA
Agents	107747	3484.903	829.0652	1896	4601	DEA
Budget	107747	1054.613	381.8441	371.2285	1658.006	DEA
% Hispanic	107747	7.699618	8.180856	0	38.93061	CPS
% Black	107747	20.6977	20.26783	0	73.07587	CPS
% Aged 0-17	107747	25.74821	2.771935	14.35	39.13191	CPS
% Aged 18-24	107747	10.37813	1.576349	5.636529	17.36039	CPS
% Aged 25-66	107747	53.52478	2.505309	41.26107	61.75636	CPS
% Male	107747	48.43827	1.158322	43.67656	53.28239	CPS
%Female Hhold	107747	39.27622	8.657475	12.76664	59.65788	CPS
% High School	107747	58.54255	4.612187	35.56177	73.50031	CPS
%Some College	107747	34.03636	5.462852	14.12591	50.3051	CPS
% College	107747	13.06181	6.929686	1.564506	33.93786	CPS
% Post-grad.	107747	6.592497	3.156708	1.564506	16.62609	CPS
Poverty Rate	107747	13.66706	4.106874	2.566354	29.11244	CPS
Unemp. Rate	107747	5.943443	1.802266	2.2	18	BLS
Crime Index	107747	477647.3	463931	15683	2061761	FBI
Post State MM	107747	.3882335	.4873505	0	1	Author
Prior State MM	107747	.183374	.3869746	0	1	Author
Federal MM	107747	.8166353	.3869671	0	1	Author
%Other Nonwhite	107747	3.135685	4.330636	0	75.59312	CPS

Table A2: MSAs Used for Overdose results

Atlanta	Baltimore	Boston	Buffalo
Chicago	Dallas	Denver	Detroit
La	Miami	Minneapolis/St. Paul	New Orleans
New York	Newark	Philadelphia	Phoenix
St. Louis	San Diego	San Francisco	Seattle
Washington DC			

Table A3: Summary Statistics for Overdose Data

Variable	Obs	Mean	Std. Dev.	Min	Max	Source
Cocaine						
Avg. Price	166	436.05	1702.4	0	14721.71	STRIDE
Avg. Purity	170	39.03681	18.72741	2.195122	84.66666	STRIDE
Std. Dev. Purity	170	34.3787	7.936098	2.516612	50.80682	STRIDE
Skewness of Purity	170	.2724356	1.221376	-3.370676	6.166441	STRIDE
Total Mentions	170	5156.074	4842.143	468.3386	21592.34	DAWN
Deaths	70	7.128571	6.875543	0	29	DAWN
Unexpected Reactions	91	1109.659	1278.486	94	5158	DAWN
Overdoses	91	638.9341	461.0733	43	1792	DAWN
Heroin						
Avg. Price	179	1782	5600	23	49988	STRIDE
Avg. Purity	176	28.85146	14.78393	1.044444	77.75	STRIDE
Std. Dev. Purity	176	24.2998	10.56431	.7071068	47.83584	STRIDE
Skewness of Purity	176	.5002679	.9303404	-2.399548	2.992001	STRIDE
Total Mentions	176	2452.808	2708.598	53.17404	11332.14	DAWN
Deaths	74	8.540541	8.802536	0	37	DAWN
Unexpected Reactions	91	308.1209	445.6308	3	2578	DAWN
Overdoses	92	458.6739	377.6237	22	1533	DAWN
MSA controls						
Response Rate	170	80.37882	9.173884	44.4	100	DAWN
Real Income	170	30398.33	6005.932	20472.13	58702	Census

Sources:
STRIDE: System to Retrieve Drug Evidence.
DAWN: Drug Abuse Warning Network (http://dawninfo.samhsa.gov).
BLS: Bureau of Labor Statistics (http://www.bls.gov).
CPS: Current Population Survey (http://www.bls.census.gov/cps/cpsmain.htm).
Census: US Census Bureau (http://www.census.gov).
DEA: Drug Enforcement Agency (http://www.dea.gov).
FBI: Federal Bureau of Investigation (http://www.fbi.gov).
BJA: Bureau of Justice Assistance (1996).