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Mandatory Minimum Sentencing, Drug Purity and Overdose Rates

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Abstract: As of 1987, the US's Anti-Drug Abuse Act (ADAA) has imposed mandatory minimum sentences for drug traffickers based on the quantity of the drug involved irrespective of purity. Using the STRIDE dataset and a differences-in-differences approach, I find that this led to increases in cocaine and heroin purity of 52 per cent and 27 per cent respectively. It also affected the distribution of purity around its mean. Using data on emergency room visits, I show that changes in the distribution of purity had significant impacts on such visits. These results provide insights useful when considering Ireland's drug policies which include the use of mandatory minimum sentences.

I INTRODUCTION

Although drug use has long been viewed as a problem, worries continue to mount as the potency of illicit substances rises. As shown in Figure 1, the average purity of street-level cocaine has increased. Figure 2 shows the same for heroin. Concurrent with this, the number of emergency room (ER) visits mentioning these drugs has increased. In addition Figures 1 and 2 show that

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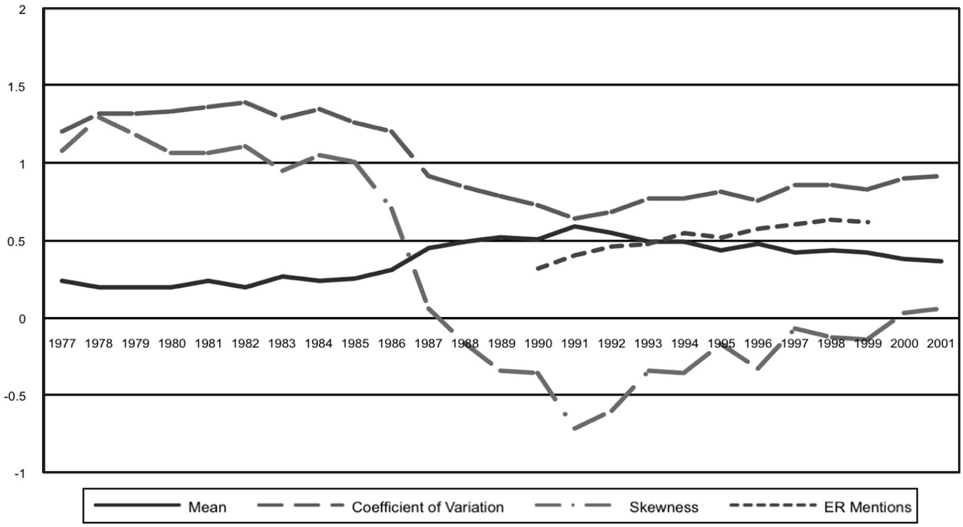
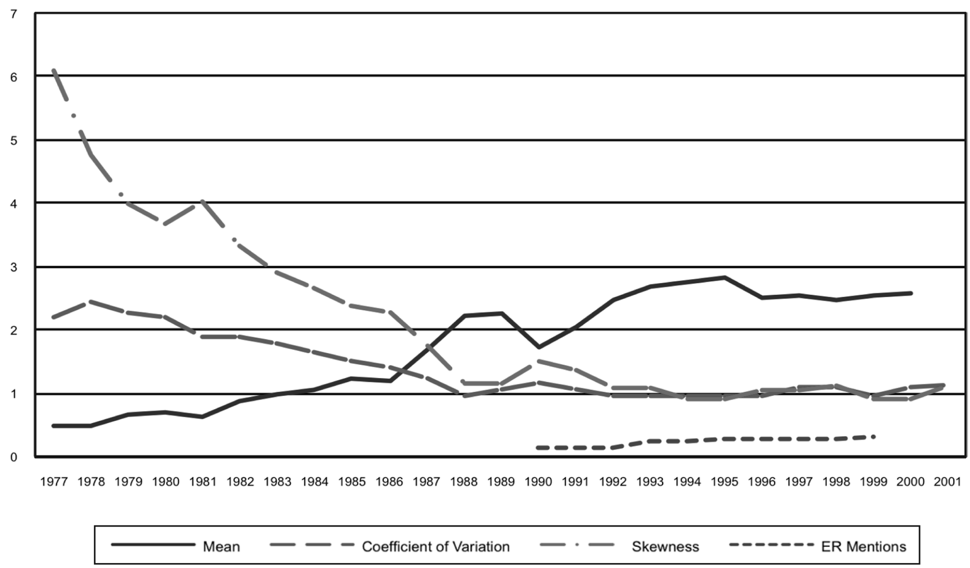
Figure 1: *Cocaine Purity and ER Mentions*



Notes: For observations of 1 gram or less. Purity ranges from 0 to 1.

Figure 2: *Heroin Purity and ER Mentions*

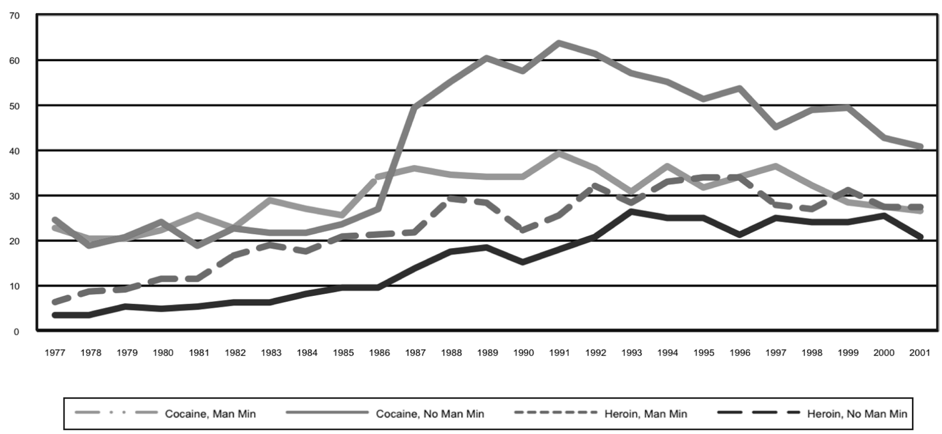


Notes: For observations of 1 gram or less. Purity ranges from 0 to 10 for easier reading.

the number of ER mentions per 100,000 people 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.[1]

In response to this concern, this paper demonstrates that 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.[2] To do this, I utilise data from 1977 to 2001 from the Drug Enforcement Agency's (DEA) System to Retrieve Information from Drug Evidence (STRIDE) database. This dataset contains information collected by the Federal Bureau of Investigation (FBI) and the DEA, including purity. For cocaine, the federal MM is associated with a 52 per cent increase in purity. For heroin, the associated increase is 27 per cent. It is important to note that this increase is significantly smaller in states that had their own comparable laws prior to the federal law. This is easily seen in Figure 3 where, especially for cocaine, there is a marked change in purity immediately following the ADAA. In addition to the increase in average purity, I find that the federal MM also lowered cocaine purity's coefficient of variation (CV) and skewness.

Figure 3: *Average Drug Purity Depending on State Mandatory Minimums*



Note: For observations of 1 gram or less. Purity ranges from 0 to 100.

[1] Examples of such claims include Drug Enforcement Agency (DEA) (2005) and Hall and Darke (1997).

[2] In contrast, Irish MMs, initially entered into force in 1999, are imposed on the value of the drugs with the current penalty of at least ten years when the value is more than €12,700 (Cassin and O'Mahony, 2006).

As well as estimating the impact of the ADAA, I investigate the relationship between purity and ER mentions. For both cocaine and heroin, I find that higher purity, lower CV, and higher skewness is generally linked to fewer ER mentions. Similar results are found for specific outcomes, including death and overdose rates. This suggests that uncertainty in drug markets plays a significant role in the health outcomes of use. This lends support to the concern expressed by Cassin and O'Mahony (2006) that Irish drug law engenders instability in the market, thereby creating uncertainty leading to increased overdoses. For the US case, however, I estimate that the ADAA reduced the extent of negative health outcomes because of the increase in purity and the reduction in the CV.

These changes brought about by the ADAA are linked to their impact on the penalties associated with drug trafficking. Chief among these was the introduction of federal MMs.[3] These MMs set forth penalties that the federal judge must impose upon conviction (although both US and Irish law allow for limited exceptions).[4] The data suggest that penalties have indeed risen. Trial defendants facing MMs are two and a half times likely to be convicted than those who did not face MMs (Jaffe, 1995).[5] Furthermore, between 1986 and 1991 the average federal prison sentence for a drug offence rose from 62 to 86 months (Bureau of Justice Statistics (BJS), 1995).[6] As Table 1 shows, the severity of the MM is increasing in the amount of the drug that is involved. 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 dilutants and adulterating substances. By enforcing MMs based upon the total weight rather than the pure weight, this increases the cost of delivering a given quantity of drugs. The predicted

[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). 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] US laws allow for two exceptions. The Violent Crime Control and Law Enforcement Act of 1994 allows non-violent first time offenders to receive reduced sentences (Bureau of Justice Statistics, 2001). In addition, those offering "substantial assistance" to law enforcement can obtain reduced sentences. According to the BJS (2001), this accounted for about 28 per cent of cases in 1999. Ennis (2003) provides a legal analysis of exceptions used in Irish courts. A study of European drug laws (European Monitoring Centre for Drugs and Drug Addiction, 2009) finds that for Ireland exceptions are the rule with only three of 55 convictions between 1999 and 2001 resulting in the minimum ten year sentence.

[5] During 1999, 62 per cent of drug convictions were under MMs with over half receiving sentences greater than 60 months (BJS, 2001).

[6] In Ireland, where available data do not distinguish between traffickers and users, the average sentence is 34 months (EMCDDA, 2009).

Table 1: *Federal Mandatory Drug Sentences for First-time Offenders*

Type of Drug		*Sentence for First Offence*	*Sentence for Second Offence*
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
	1,000 plants or 1,000 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).

response to this is clear: to avoid harsher penalties and higher costs, both consumers and producers would prefer to trade in smaller, purer amounts. Although federal law only applies when tried in federal court (which tries a minority of cases), given the severity of the penalties, one would still expect dealers to respond. Further, one might expect dealers to respond the most in states where penalties are initially low.

This is in fact borne out by the data. 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 would be smaller in these states because dealers may have already shifted towards higher purities in response to the state-level MMs. Table 3 reports the average purity for drug observations 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 in Table 3 and Figure 3, this increase is indeed largest for states without 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.

These changes in purity can lead to changes in the health outcomes of use. Looking at the data from the Drug Abuse Warning Network (DAWN)

Table 2: *State Mandatory Minimums for Repeat Drug Offenders*

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

Table 3: *Average Purities for Observations Under 1 Gram*

	Cocaine		*Heroin*	
	Prior to 1987	*After 1987*	*Prior to 1987*	*After 1987*
State MM instituted prior to 1987	26.75	33.53	14.11	27.92
No state MM	22.95			
	51.06	6.56	22.49	
State MM instituted after 1987		35.50		33.75

illustrated in Figures 1 and 2, the number of ER episodes mentioning the use of cocaine or heroin appears to move in conjunction with measures of the distribution of purity. While one might expect users to condition consumption on the average purity in their market, as suggested by Cassin and O'Mahony (2006) other distributional changes that affect the uncertainty regarding purity might be more difficult to respond to. As such, a higher CV or skewness might either lead to more ER mentions due to a greater risk of consuming too much or to fewer mentions if risk-averse users reduce use due to greater uncertainty.

For both cocaine and heroin, I find that a higher CV increases ER mentions. This is consistent with greater uncertainty increasing negative health outcomes. On the other hand, higher skewness (i.e. a longer tail in the higher purities) reduces ER mentions. This might arise if a greater chance of consuming a very high purity deters use. Although its coefficient is less robust (especially for heroin), higher average purity is also linked to fewer ER mentions which might be attributable to higher purity implying fewer harmful adulterants. Using another, heretofore unused database provided by the DAWN, I find that the number of deaths, overdoses and unexpected reactions from heroin and cocaine use respond to changes in purity's distribution in ways comparable to ER mentions.

The remainder of the paper is as follows. Section II describes the estimation methodology and the data. Section III contains the results regarding the effect of MMs on drug purity, including the effect on the CV and skewness. Section IV investigates the effect of purity changes on ER mentions and outcomes. Section V concludes.

II EMPIRICAL METHODOLOGY AND DATA

To motivate my empirics, consider a simple model of a profit-maximising drug dealer. Expected profits from dealing an amount Q of purity R are:

$$\pi^e (Q,R) = P(R,Q)Q - C(R,Q) - aJ(Q;M) \quad (1)$$

where $P(R, Q)$ is the price per gram, $C(RQ)$ is the cost of producing (or purchasing from another distributor) an amount Q with purity R, a is the probability of being arrested and convicted, and $J(Q)$ is the monetary cost of being convicted of dealing a quantity Q. Assume that $P_{12}(R, Q) < 0$. The production cost $C(R, Q)$ is an increasing convex function in both arguments (with a positive cross-partial). The jail-time cost $J(Q; M)$ is an increasing convex function of M, a term reflecting the degree of enforcement. One reason for a rise in M is the imposition of MMs, i.e. they lead to an increase in the legal penalty of dealing a given quantity regardless of the purity. The first order conditions from maximising (1) are:

$$P_1(R,Q)Q - C_1(R,Q) = 0 \quad (2)$$

and

$$P_2(R,Q)Q + P(R,Q) - C_2(R,Q) - aJ_Q(Q;M) = 0 \quad (3)$$

From these, where $\Delta \equiv [P_{11}Q - C_{11}][P_{22}Q + P_2 + P_2 - C_{22} - qJ_{QQ}] - [P_{12}Q + P_1 - C_{12}]^2 > 0$

$$\frac{dR}{dM} = -\frac{aJ_{QM}\,[P_{12}Q + P_1 - C_{12}]}{\Delta} > 0 \quad (4)$$

i.e. an increase in the penalties associated with a MM leads to an increase in purity. On this issue, note the results of Caulkins and Padman (1993), who investigate cocaine users' willingness to substitute between purity and quantity. Using the STRIDE drug price data, they find that consumers pay more for two grams with 30 per cent purity than for one gram with 60 per cent purity. Thus, although drug markets may shift from quantity towards purity due to MMs, they would not switch to an entirely pure product.

I turn now to my data. The unit of observation in my data is an individual drug transaction. Specifically, I estimate the following specification:

$$Purity_{i,s,t} = \alpha_0 + \alpha_1 S_s + \alpha_2 T_{s,t} + \alpha_3 X_i + \alpha_4 ManMin_{s,t} + \alpha_5 Z_t + \alpha_6 Y_{s,t} + \varepsilon_{i,s,t} \quad (5)$$

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 $\varepsilon_{i,s,t}$.[7] 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.

Information on a drug transaction comes from the DEA's STRIDE database, which contains information on cocaine and heroin transactions by the Federal Bureau of Investigation and the DEA. Note a transaction can either be a purchase or a seizure. For this study, I use data from 1977 to 2001 since information from ongoing investigations is withheld by the DEA impacting the data after 2001.[8,9] For each transaction, the date and location of the transaction are logged as well as the quantity and purity of the drug seized. In my estimates I use transactions for powder cocaine (HCl) and hydrochloride salt heroin.[10] In addition to the above information, if the transaction was a purchase, the STRIDE data reports the price negotiated for the given amount. Given the endogeneity of price and quantity in the model, they were not used as controls.[11] However, a dummy variable *Purchase* was created that equals one when the transaction was a purchase. Following Horowitz (2001) to focus on "street-level" transactions, quantity was used to

[7] Note that since I am using retail purity, I am assuming that either changes in import purity are negligible or are sufficiently captured by the time trends.

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

[9] 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 .

[10] The STRIDE data also includes information on crack and tar heroin, however, these were made available to me. See Caulkins, *et al.* (2004) for discussion of trends in the crack market.

[11] In unreported results, two price variables – the price per gram and the total transaction price – were used just for the purchased sub-sample. Other unreported results used quantity despite potential endogeneity. All of these yielded comparable results.

create a sub-sample of transactions involving one gram or less. Observations with missing information were deleted. International observations were deleted, thus my sample is composed of observations from the fifty US states plus Washington DC (all of which I refer to as "states").[12] Observations with purities greater than 100 and/or quantities equal to zero were also deleted.[13] This left 325,129 cocaine observations and 103,568 heroin observations. In addition to these, the date was used to construct eleven month dummies.[14]

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 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 enforcing 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.[15] Similar to the interaction term, I expect that the imposition of a state MM on top of the federal one to have a negative effect on purity. Note that since the state variables only equal one after a state begins enforcing its own law and the interaction and *Post State MM* variables do not activate until after 1987, these are not perfectly correlated with the state fixed effects.

These state-level MM variables were created from information collected through communication with state attorney general offices and law

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

[13] A sizable number of observations report zero purity. This could be an actual zero purity or a transaction where no purity analysis was performed (potentially due to a quantity too small to perform the analysis). Estimates excluding these transactions found similar results.

[14] December was the omitted month. Note that these month dummies net out the year-invariant average difference across months, i.e. seasonal variation, and thus do not preclude the use of year-varying variables.

[15] Note that since all of these state laws are enacted no earlier than 1987, interacting this with *Federal MM* would yield the same variable.

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.[16] Thus, some states do not have MMs for the initial offence, but do for the second or third offence. In addition, some states had MMs for very specific offences 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.[17] In addition to these, I include a number of state-level variables to control for legal enforcement, demographic, and income effects. The Data Appendix describes these in detail and also includes summary statistics in Table A1.

Within the data, there are two concerns. First, it may be that the observations represent a biased sample if the dealers targeted by the DEA are not representative of average dealers.[18] In the context of this study, 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 below it would be necessary for the DEA change its targeting towards 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.

Second, there is the possibility that state-level MMs may depend on purity, i.e. states with higher purities may be more likely to form their own MMs. The possibility of such an endogeneity bias is unlikely in this study for two reasons. First, the unit of observation is a single transaction and such laws are

[16] Some states also have mandatory minimums specific for violent offenders or sex offenders. Since this differs significantly from the federal law, I do not count this as a drug offence mandatory minimum.

[17] While there is a great deal of variation across states in terms of the number of offences needed to trigger the MM and the severity of the punishment it entails, the complexity and degree of heterogeneity makes it impossible to construct a meaningful variable exploiting these details. Furthermore, several states changed the severity of the penalty. Since I am unable to obtain detailed information on the dates of these revisions, I use this simple dummy variable approach.

[18] Horowitz (2001) uses this argument to critique the STRIDE's price data.

not written as the result of a single transaction. Second, given the time lag to draft and pass such legislation, if anything the existence of a state MM would depend on purity several years before it is initially implemented (something that itself is rejected in unreported results).[19] Nevertheless, as a final safeguard, state fixed effects and state specific time trends are included to filter out the state-specific averages and trends.

III THE IMPACT OF MANDATORY MINIMUMS ON PURITY

Table 4 reports OLS estimates of the impact of MMs on cocaine purity (columns 1-3) and heroin purity (columns 4-6).[20] In columns 1 and 4, the full sample is used. In columns 2, 3, 4 and 5, I restrict the data to those observations with quantities less than or equal to one gram. In columns 3 and 6, I use year dummies. Note that the year dummies absorb the *Federal MM* variables.

As columns 1 and 2 show, *Federal MM* is positive and highly significant for cocaine. For the full sample, the estimated coefficient is 25.4. When compared to the average purity of the sample of 32 per cent, this implies a 79 per cent increase in purity after the federal MMs took effect. Note that the magnitude of this change is roughly equal to the increase in average purity during the three years surrounding the implementation of the federal MMs. In the "street-level" cocaine sample, the estimated impact is 21.4 percentage points. Compared to the purity average of 41.3 in this sample, the federal MM increased the purity by about 52 per cent. As predicted, the total impact of the federal law is smaller in states that had their own pre-existing MMs where it is just over half as large as in states without their own MMs. Looking at Figure 3, this result is expected. In each case I reject the null that these two effects offset one another, indicating that there was a significant increase in purity even if a state had its own pre-existing MM.

Looking at the estimated impact of the state-level MMs themselves, the prior state MMs are linked to increase purity although only when using the full sample. This suggests that state laws had an impact only for relatively

[19] When estimating a Probit model on whether a state has its own MM as a function of lagged purity of up to five years along with the other state-level controls, excepting the one year lag in cocaine, lagged purity was never significant. Since t is extremely unlikely that states could institute a law so swiftly (and that previous year purities do not matter at all), this further alleviates concerns of endogeneity.

[20] Numerous alternative specifications were used, including a post-1985 dummy variable, Tobit, the log of purity, quantity and/or price as control variables, excluding zero purities, sub-samples only using states with 50 or more observations per year, and the full sample. All of these yielded similar qualitative results and are available on request.

Table 4: *The Impact of Mandatory Minimums on Purity*

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
		Cocaine			*Heroin*	
	All Quantities	*≤ 1 Gram*	*≤ 1 Gram, Year FE*	*All Quantities*	*≤ 1 Gram*	*≤ 1 Gram, Year FE*
Federal MM	25.437***	21.483***		8.739***	5.355***	
	(3.744)	(4.171)		(2.146)	(1.634)	
Prior State MM	–9.950**	–9.398**		–5.233**	–2.213	
*Federal MM	(3.766)	(4.631)		(2.434)	(2.414)	
Prior State MM	10.100***	2.009	0.617	–4.556**	–4.23***	–4.036*
	(3.288)	(5.664)	(5.324)	(1.894)	(1.374)	(2.063)
Post State MM	–4.813**	–0.281	0.581	3.248	7.592*	9.016***
Other controls:						
Agents	(2.089)	(3.250)	(3.296)	(2.612)	(3.963)	(3.128)
	–0.010***	–0.005*	–0.030***	–0.007***	–0.005**	–0.001
	(0.002)	(0.003)	(0.008)	(0.002)	(0.002)	(0.009)
Budget	–7.08e-8*	–1.05e-7*	6.38e-07***	–8.4e-8***	–4.2e-8*	4.26e-08
	(3.54e-08)	(5.30e-08)	(1.46e-07)	(2.41e-8)	(2.18e-8)	(1.53e-7)
Crime Index	8.05e-11	1.6e-10***	4.11e-11	8.61e-11*	2e-10***	2e-10***
	(6.63e-11)	(5.30e-08)	(8.36e-11)	(4.9e-11)	(4.4e-11)	(6e-11)
Total Obs	0.001*	0.001**	0.001*	–0.0003	–0.002**	–0.005**
	(0.0004)	(0.0005)	(0.001)	(0.001)	(0.001)	(0.002)
State Intensity	65.253***	52.349***	30.918*	10.988	4.803	19.771*
	(17.469)	(15.974)	(15.517)	(9.935)	(7.526)	(11.400)
Population	–1.10e-15	–6.4e-15*	–5.74e-15	1.65e-15	–6e-15***	–8e-15***
	(3.37e-15)	(3.17e-15)	(3.72e-15)	(2e-15)	(1.7e-15)	(2.3e-15)
GSP	–3.33e-11	3.57e-11	1.38e-11	–5e-11***	2.75e-11	1.48e-11
	(3.41e-11)	(3.50e-11)	(3.14e-11)	(1.7e-11)	(3e-11)	(2.9e-11)
Income	5.07e-10	–3.89e-11	5.45e-10	1.83e-9**	9.89e-11	1.47e-10
	(6.52e-10)	(6.45e-10)	(8.91e-10)	(8.9e-10)	(5.8e-10)	(6.4e-10)
Poverty Rate	0.268	–0.276**	–0.905***	0.178	–0.141	–0.353**
	(0.168)	(0.128)	(0.172)	(0.233)	(0.178)	(0.174)
Unemp. Rate	0.322	0.626**	0.487	0.436	0.531	1.179***
	(0.282)	(0.247)	(0.397)	(0.389)	(0.408)	(0.405)
% Male	–1.376***	–0.439	0.562	–0.048	0.714**	0.767**
	(0.355)	(0.271)	(0.457)	(0.394)	(0.274)	(0.328)
% Female	–0.576***	–0.089	0.566**	–0.548***	–0.109	0.071
Household	(0.165)	(0.196)	(0.228)	(0.166)	(0.150)	(0.134)
% Hispanic	1.030***	1.950***	1.843**	0.650**	0.899**	0.712
	(0.344)	(0.681)	(0.702)	(0.315)	(0.370)	(0.484)
% Black	–0.781**	–1.067***	–0.802**	0.012	0.034	–0.190
	(0.296)	(0.284)	(0.303)	(0.370)	(0.269)	(0.317)
% Other	0.368	0.998	0.688	0.686*	1.070**	0.877*
Nonwhite	(0.546)	(0.643)	(0.578)	(0.359)	(0.494)	(0.506)
% Aged 0-17	1.374***	1.826***	0.723	0.551	–0.051	–0.539
	(0.439)	(0.420)	(0.559)	(0.448)	(0.364)	(0.554)

Table 4: *The Impact of Mandatory Minimums on Purity (contd.)*

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
		Cocaine			*Heroin*	
	All Quantities	*≤ 1 Gram*	*≤ 1 Gram, Year FE*	*All Quantities*	*≤ 1 Gram*	*≤ 1 Gram, Year FE*
% Aged 18-24	0.243	0.619*	0.481	–0.881	–1.004	–1.92***
	(0.549)	(0.350)	(0.466)	(0.592)	(0.648)	(0.559)
% Aged 25-66	1.008***	0.936**	–0.138	0.271	0.245	–0.122
	(0.373)	(0.466)	(0.518)	(0.331)	(0.424)	(0.485)
% High School	1.123***	0.629	–0.274	0.731**	–0.041	–0.225
	(0.307)	(0.377)	(0.516)	(0.297)	(0.303)	(0.388)
% Some College	1.003**	0.671	–0.147	1.343***	0.601	0.415
	(0.405)	(0.537)	(0.497)	(0.469)	(0.429)	(0.379)
% College	0.785*	0.767	–0.238	1.878***	0.984**	0.302
	(0.442)	(0.473)	(0.549)	(0.465)	(0.427)	(0.887)
% Post-graduate	0.567	0.222	0.309	0.983*	0.197	0.221
	(0.492)	(0.554)	(0.600)	(0.543)	(0.547)	(0.647)
Purchase	5.393***	22.870***	22.934***	–3.688*	7.021**	7.126**
	(0.793)	(4.615)	(4.619)	(1.857)	(2.682)	(2.700)
Constant	–3.001	–34.433	36.145	–78.874	–12.508	33.108
	(55.337)	(57.542)	(82.877)	(50.836)	(44.383)	(47.091)
Observations	325,129	104,813	104,813	103,568	41,802	41,802
R-squared	0.109	0.240	0.243	0.419	0.237	0.242
H_0: Federal MM + Prior State MM* Fed. MM = 0	32.01***	10.51***	–	2.36	2.62	–
H_0: Prior State MM = Post State MM	13.04***	0.12	0.0001	5.18**	6.58**	8.33***

All specifications include state-specific trends, month dummies, and state fixed effects. Robust standard errors in parentheses. Errors are corrected for clustering on states.
* significant at 10 per cent; ** significant at 5 per cent; *** significant at 1 per cent.

large quantities of cocaine. State MMs enacted after 1987, however, are associated with lower purity. Since these laws then took effect after the federal ones, as with the interacted term discussed above, this may signal a smaller marginal impact of the federal MM relative to these states' state-specific means. Turning to column 3, note that when using year dummies, the state MMs have no effect.[21] This is important because it provides further evidence

[21] This is also true when combining them into a single state MM variable.

that states with their own MMs prior to 1987 did not implement them due to higher purities.

Turning to the heroin results, I again find that the federal MM is positive and significant. In the full sample, the estimated coefficient of 8.7, when compared to the average purity of 32, implies a percentage increase of 27 per cent. For the street level sample, where the average purity is 17.8, the estimated impact is a 30 per cent increase in purity. When using the full sample, this rise is again smaller for states with pre-existing MMs. Although the coefficient on the interaction is still negative when using the street-level sample in column 5, I cannot reject the null that the increase is the same for states with and without their own MMs. Unlike the cocaine regressions, states instituting prior MMs generally have lower purity, again arguing against the idea the early adopters were high purity states. Finally, unlike the cocaine results, the estimates on *Post-State MM* is positive and significant in columns 5 and 6 suggesting that, as with the federal law, these state MMs raised purity.

Since the time-variation in the purity of powder cocaine may be influenced by the rise of crack cocaine, 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 in this market. However, it is unclear that the introduction of crack would also attract low-purity heroin users. Furthermore, this does not explain why these effects would differ by state according to pre-existing state-level MMs. Unfortunately, I do not have access to crack data, one of the reasons I include the crime index which, given the pattern of behavior for crack users, should be correlated with crack use. 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.

Turning to the other controls, *Agents* and *Budget* are generally negative and significant. *Crime Index*, *Total Obs*, and *State Intensity* tend to be 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). These latter three are consistent with the notion that high crime regions might attract greater law enforcement, increasing the incentive to shift towards higher purities. Higher purities also tend to be found in states with more Hispanics and fewer blacks. Purchased observations generally have greater lower purity than seizures. The robustness of the other variables is slight which is not surprising given the use of state fixed effects and state specific time trends.

Thus, the data are consistent with an effect of federal MMs on the purity of cocaine and heroin. One natural concern is that this is capturing some in drug markets over time not captured by the state-specific time trends or the other variables. The significance of the interaction term helps to alleviate this. Nevertheless, as an additional check on the impact of MMs, I also utilised the international data available in the STRIDE database. There, I used these data to estimate the effect of US federal MMs on observations in the STRIDE data from other drug importing countries (i.e. the OECD countries).[22] Since the MMs are only effective for within the United States, their introduction should 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, where I also control for a common time trend and country fixed effects, *Federal MM* is insignificant in the cocaine and significantly negative in the heroin regressions. While there are many reasons for why these observations may differ from those within the US, this adds further evidence that this federal MM variable is capturing something other than a simple positive change in the trend of drug purity.

Table 5: *US Mandatory Minimums and International Observations*

	(1) *Cocaine*	*(2)* *Heroin*
Federal MM	–1.330	–17.073***
	(2.107)	(2.600)
Trend	0.015	0.517***
	(0.160)	(0.184)
Constant	80.216***	51.239***
	(2.135)	(1.361)
Observations	1,071	1,744
R-squared	0.069	0.072

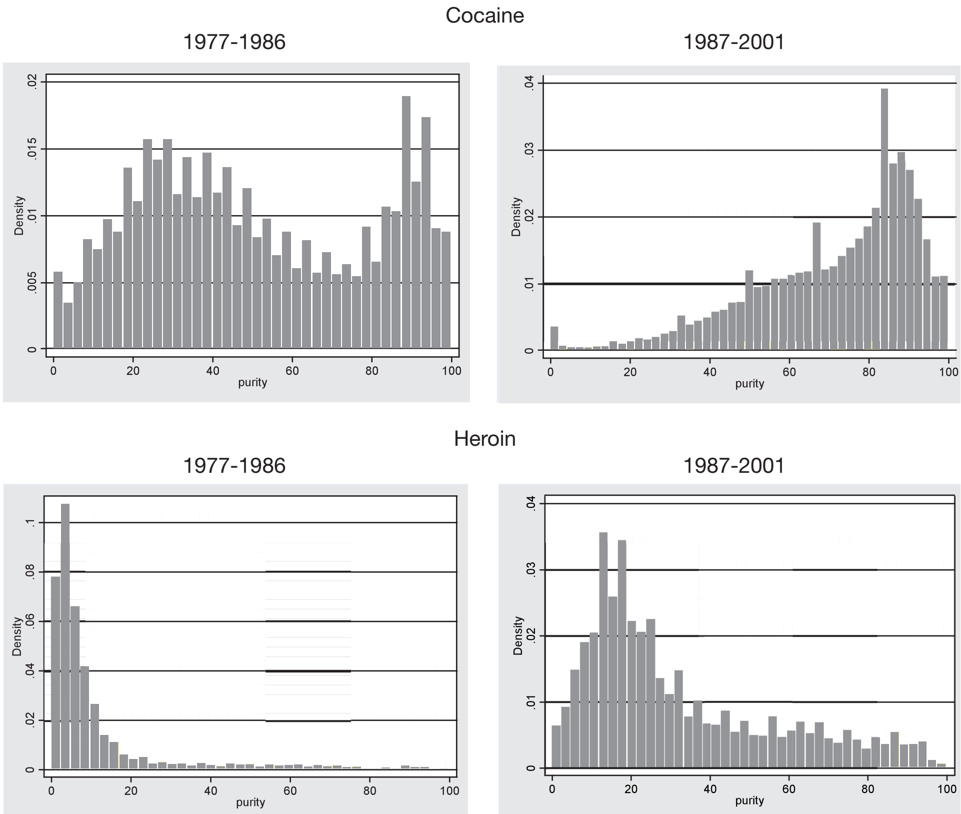
All specifications include country fixed effects. Robust standard errors in parentheses.
* significant at 10 per cent; ** significant at 5 per cent; *** significant at 1 per cent.

In addition to the impact on average purity, MMs may affect other moments of purity's distribution. Figure 4 illustrates histograms for the purity of observations under one gram 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 heroin purity.

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

Compared to their means, these changes in dispersion resulted in downward trends in the CV of purity for both drugs as illustrated in Figures 1 and 2. There are reasons to think that these changes may be linked to the ADAA. On the one hand, the ADAA may have led to a decentralisation of the drug dilution process due to a desire to maintain purity further down the distribution chain. This greater number of dealers diluting the drug could increase the spread around the mean. Alternatively, the spread could fall. 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.[23] As more dealers are apprehended and become repeat offenders, this might reduce dispersion. Understanding these

Figure 4: *Distribution of Purity for Observations Under One Gram*



Source: STRIDE.

[23] Unfortunately, data on the offender is not available from the STRIDE database.

potential effects is important when examining the impact of purity on drug use outcomes.

Table 6 therefore presents estimates using the annual state-level mean, the coefficient of variation, and the skewness of purity.[24] All of these were constructed using only those observations with a quantity less than or equal to one.[25] The controls are the same as in Table 4, with the exception of *Purchase* which is now the percentage of observations that were purchased for each state-drug-year. Again, errors are clustered by state. Consistent with the above results, the mean is greater following the introduction of the federal MM for both cocaine and heroin. For cocaine, the federal MM is correlated with a reduction in both the CV and skewness. These estimates suggest that after 1987 the distribution of cocaine purity became less dispersed around its higher mean and had a longer tail in low purities. For heroin, the federal law has no impact on either the CV or skewness directly. However, the CV and skewness rose after the federal MM took effect for states with prior MMs. This would suggest greater dispersion and a longer high purity tail in these states. In addition, similar to the federal law for cocaine, I now find a negative effect on CV and skewness for states that added their own MMs after 1987.

IV 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. 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 US as a whole the number of emergency room episodes (ER mentions per 100 people) that mentioned cocaine or heroin use rose markedly during the 1990s. At the same time, the average purity of cocaine fell while that of heroin rose (although both were significantly higher than they were before 1987). Thus, at least the heroin numbers suggest that higher average purity levels increase ER mentions. However, as Figures 2 and 3 show, there were other marked changes in the distribution of purity. For cocaine, both the CV of purity and the skewness of purity rose during the 1990s. For heroin, there was relatively little change in these moments. Given the results in Table 6,

[24] I use annual aggregates here to match the analysis in the next section.

[25] Comparable results were found when omitting zero purities in the construction of these variables.

Table 6: *The Effect of MMs on the Distribution of Purity*

	Cocaine			*Heroin*		
	(1) *Mean*	*(2)* *CV*	*(3)* *Skewness*	*(4)* *Mean*	*(5)* *CV*	*(6)* *Skewness*
Federal MM	12.932***	–0.246**	–0.684***	6.442*	–0.186	–0.197
	(3.390)	(0.114)	(0.159)	(3.781)	(0.153)	(0.225)
Prior State MM	1.361	0.075	0.246	–11.115*	0.399*	0.632*
*Federal MM	(4.816)	(0.152)	(0.250)	(5.565)	(0.235)	(0.330)
Prior State MM	–5.704	0.093	–0.207	–5.124	0.023	–0.896
	(9.243)	(0.361)	(0.526)	(3.192)	(0.945)	(2.317)
Post State MM	1.491	–0.135	–0.189	7.213	–0.40***	–0.865***
Other controls:						
Agents	(3.222)	(0.101)	(0.151)	(4.423)	(0.113)	(0.223)
	–0.008***	0.0001	0.0003**	–0.005	0.001	0.001*
	(0.003)	(0.0001)	(0.0001)	(0.004)	(0.0002)	(0.000)
Budget	6.12e-08	–2.99e-09	–3.39e-09	–7.09e-8	–3.08e-09	–6.92e-09
	(5.55e-8)	(1.96e-9)	(2.86e-9)	(6.42e-8)	(3.18e-9)	(5.5e-9)
Crime Index	1.34e-10	–6e-12**	–1e-11***	1.06e-10	–9.e-12**	–3e-11***
	(9.35e-11)	(3.1e-12)	(4.5e-12)	(9.2e-11)	(3.9e-12)	(8.9e-12)
Total Obs	0.002	–0.00002	–0.0001	–0.004	–.00001	0.001*
	(0.001)	(0.00005)	(0.0001)	(0.003)	(0.0001)	(0.000)
State Intensity	19.991	–0.189	–1.392	33.401	–1.953	–1.484
	(46.287)	(1.188)	(3.295)	(24.907)	(1.205)	(1.999)
Population	–3.58e-17	1.50e-16	4.4e-16*	–1.8e-15	1.86e-16	5.97e-16
	(5.54e-15)	(1.5e-16)	(2.3e-16)	(5.2e-15)	(3e-16)	(5.1e-16)
GSP	2.49e-12	–2.53e-12	–4.2e-12*	9.2e-11**	–3.0e-12	–1.99e-12
	(3.67e-11)	(1.6e-12)	(2.5e-12)	(42 -11)	(2e-12)	(3.1e-12)
Income	–4.32e-10	5.89e-11	7.93e-11	3.39e-10	4.46e-11	4.30e-12
	(1.03e-09)	(4.0e-11)	(5.7e-11)	(1.2e-09)	(6e-11)	(1.0e-10)
Poverty Rate	–0.020	0.022*	0.021	0.290	–0.002	–0.004
	(0.269)	(0.012)	(0.015)	(0.473)	(0.015)	(0.021)
Unemployment	0.274	–0.002	0.018	1.261**	–0.011	–0.012
Rate	(0.535)	(0.018)	(0.027)	(0.588)	(0.019)	(0.048)
% Male	–0.073	–0.005	0.009	0.477	0.023	0.001
	(0.859)	(0.024)	(0.032)	(0.660)	(0.030)	(0.059)
% Female	–0.277	0.006	0.013	–0.196	0.017	0.027
Household	(0.233)	(0.009)	(0.012)	(0.232)	(0.011)	(0.020)
% Hispanic	0.016	0.004	–0.012	1.106	–0.050*	–0.101*
	(0.525)	(0.019)	(0.022)	(0.762)	(0.028)	(0.059)
% Black	–0.123	–0.020	–0.024	–0.731	0.004	–0.018
	(0.499)	(0.016)	(0.023)	(0.496)	(0.019)	(0.032)
% Other	–0.184	0.041	0.032	1.692**	–0.026	–0.105**
Nonwhite	(0.654)	(0.032)	(0.047)	(0.635)	(0.019)	(0.052)
% Aged 0-17	1.044**	–0.010	–0.054*	0.728	0.028	0.052
	(0.478)	(0.018)	(0.029)	(0.864)	(0.030)	(0.055)

Table 6: *The Effect of MMs on the Distribution of Purity (contd.)*

	Cocaine			*Heroin*		
	(1) Mean	*(2) CV*	*(3) Skewness*	*(4) Mean*	*(5) CV*	*(6) Skewness*
% Aged 18-24	0.609	–0.006	–0.035	–1.810*	0.071	0.111*
	(0.591)	(0.020)	(0.028)	(0.925)	(0.042)	(0.063)
% Aged 25-66	0.996	–0.021	–0.043	–0.447	0.039	0.018
	(0.726)	(0.024)	(0.032)	(0.749)	(0.036)	(0.066)
% High School	0.294	0.012	0.002	1.655**	0.002	0.033
	(0.503)	(0.020)	(0.032)	(0.805)	(0.026)	(0.050)
% Some College	0.424	0.012	0.013	1.297	–0.009	–0.002
	(0.499)	(0.020)	(0.025)	(0.843)	(0.031)	(0.057)
% College	0.018	0.007	–0.008	1.485*	–0.013	–0.015
	(0.557)	(0.021)	(0.026)	(0.775)	(0.031)	(0.057)
% Post-graduate	–1.139	0.042	0.032	–0.037	0.010	0.011
	(1.034)	(0.050)	(0.066)	(1.276)	(0.049)	(0.088)
Purchase	33.411***	–1.237***	–1.485***	8.57***	–0.53***	–0.241
	(3.117)	(0.101)	(0.164)	(3.081)	(0.098)	(0.179)
Constant	–47.368	0.433	0.527	–71.776	–4.312	–5.088
	(78.365)	(2.168)	(3.397)	(79.631)	(3.053)	(6.636)
Observations	1,099	1,055	1,050	754	725	717
R-squared	0.458	0.472	0.447	0.539	0.387	0.580
H0: Federal MM + Prior State MM* Fed. MM = 0	9.13***	1.31	3.22	.69	.85	.153
H0: Prior State MM = Post State MM	.52	.55	0.001	4.76**	.20	0.001

All specifications include state-specific trends and state fixed effects. Robust standard errors in parentheses. Errors are corrected for clustering on states.
* significant at 10 per cent; ** significant at 5 per cent; *** significant at 1 per cent.

understanding how these moments relate to health outcomes gives insight into the possible impacts of the federal MM.

Although one might expect drug users to reduce consumption in response to higher expected purity, survey evidence by Darke, Hall and Ross (1996) finds that this is rarely the case. Further, changes in the uncertainty about purity, as embodied in the CV and skewness, can be more difficult to adjust to.[26] As described by the National Institute on Drug Abuse (2004b), the wide

[26] Within the medical literature, there is a body of evidence finding that the variations in average purity have implications for overdose rates. For cocaine, Platt (1997) provids an overview. Risser, *et al.* (2007) is a recent example for heroin.

variation in street-level heroin purity is a primary reason for heroin overdoses. Holding the number of users constant, a higher CV of purity may increase the number of negative outcomes from use, increasing ER mentions. However, this greater risk might lead to fewer users thereby lowering the number of ER mentions. Similarly, a higher skewness (a longer tail in the higher purities) might increase ER mentions since an unexpectedly high purity likely has more severe health consequences than unexpectedly low purity. Alternatively, this more "high end" uncertainty may frighten off users and lower ER mentions.

To investigate these possibilities, I utilise 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. These data were used by Caulkins (2001), Hyatt and Rhodes (1995), and Dave (2006) to estimate the effect of drug prices on mentions. Following these studies, I use a reduced form specification where the number of ER mentions per 100,000 for drug d in MSA m in year t is:

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

where $Avgprice_{d,m,t}$ 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. Unlike those studies, in some specifications I also control for the average purity, the CV of purity, and the skewness of purity for a given drug, MSA, year observation. The average price and the three purity variables were all constructed using observations with quantities less than one gram.[27] The purity variables were calculated using all the observations; those for average price per pure gram utilised only purchased observations. 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 7 presents the results for total ER mentions; columns 1 through 3 are for cocaine, 4 through 6 are for heroin.[28] Column 1 presents a baseline

[27] This differs from Dave (2006) 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.

[28] In unreported results, I also used the heroin variables as controls in the cocaine regressions and vice versa to test for substitution between drugs. Some evidence for this was found. Results are available on request.

cocaine specification that is comparable to the existing literature, including only the average price, a trend, real income, and the response rate. Consistent with those 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 average purity, the CV, and skewness to the baseline specification. I find that higher average purity implies fewer ER mentions. This would be consistent with higher average purity implying fewer harmful adulterants, reducing the risk of use. During the 1990s, the average cocaine purity fell by 9.3 percentage points. This would translate into 399 more ER mentions, a 7.6 per cent increase relative to the sample mean.[29] Higher CV, on the other hand, significantly increases cocaine ER mentions as one would expect if uncertainty is a risk for users. Using the .1 increase in CV during the 1990s, this implies 516 more mentions, or a 9.9 per cent increase relative to the mean. Higher skewness implies significantly fewer ER mentions. This suggests that more positively skewed distributions deter usage and reduce ER mentions. Using the .21 skewness increase during the 1990s, this would translate to 386 fewer mentions, or a drop of 7.3 per cent relative to the mean. In column 3, I also introduce MSA fixed effects. Of the key variables, although the signs of the estimated coefficients remain the same, only the skewness coefficient remains significant.

Columns 4 through 6 repeat this analysis for heroin. The pattern and significance of the coefficients matches that for cocaine with the exception that average purity, although still negative, is never significant. Again using the changes during the 1990s, the fall in CV of .13 implies a reduction in mentions of 289, or a fall of 12 per cent relative to the mean. The decline in skewness of .56, on the other hand, implies an increase in mentions of 766, a rise of 31 per cent relative to the mean.

In addition to considering the changes during the sample period, one can estimate the impact of the federal MM on ER mentions. Using the estimates of Table 6 and columns 2 and 5 of Table 7, the net impact of the federal MM would be a reduction in cocaine mentions of 560 and a reduction in heroin mentions of 175. Unfortunately, due to lack of data, this cannot be compared to the actual change in mentions following the introduction of the federal law. Nevertheless, it suggests that one potential benefit of the ADAA could have been a reduction in ER visits by users.

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

[29] In this and all comparable subsequent calculations, this is the number of cases per 100,000.

Table 7: *Purity and Emergency Room Mentions*

		Cocaine			*Heroin*	
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Avg. Price	–0.348***	–0.429***	–0.090	–0.029**	–0.034**	–0.007
	(4.07)	(0.133)	(0.085)	(0.014)	(0.016)	(0.019)
Avg. Purity		–42.702**	–3.287		–4.845	–8.627
		(17.914)	(6.375)		(13.145)	(8.616)
CV of Purity		5,157.17**	197.587		2,220.117***	429.003
		(2,133.256)	(840.257)		(622.918)	(328.901)
Skewness of Purity		–1,841.607***	–374.495**		–1,368.066***	–460.619***
		(540.757)	(170.391)		(254.698)	(150.464)
Other controls:						
Trend	–38.361	–89.352	308.896***	–31.162	–69.173	239.173***
	(0.30)	(129.663)	(71.752)	(48.102)	(55.309)	(73.660)
Real Income	0.141*	0.234***	–0.163***	0.290***	0.328***	–0.119
	(1.83)	(0.077)	(0.058)	(0.040)	(0.043)	(0.094)
Response Rate	3.475	–20.215	–38.524	11.307	27.749	10.322
	(0.10)	(44.274)	(30.791)	(17.650)	(17.675)	(17.859)
Constant	77,255.027	177,181.460	–603,163.364***	55,053.793	127,842.802	–471,755.524***
	(0.31)	(257,154.815)	(142,500.531)	(95,418.224)	(109,813.670)	(145,187.391)
Observations	166	160	160	179	170	170
R-squared	0.04	0.179	0.930	0.233	0.373	0.898
			MSA Fixed Effects			MSA Fixed Effects

Robust standard errors in parentheses. * significant at 10 per cent; ** significant at per cent; *** significant at 1 per cent.

for 1995 to 2001.[30] To my knowledge, these data have yet to be used by economists.[31] 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. The controls are the same as columns 2 and 5 above.

Across the specifications, two findings are fairly robust. First, the estimated signs of the coefficients are comparable to those for total ER mentions, i.e. lower prices, higher purity, lower CV and higher skewness all reduce these outcomes. Second, the coefficients for CV and skewness are generally the most significant. The exception to this is death from heroin use. One potential explanation for this difference between heroin and cocaine deaths is that long-term cocaine users become more sensitive to the drug's anaesthetic and convulsant effects which are linked to the primary causes of death from cocaine use (National Institute on Drug Abuse, 2004a). Users of opiates such as heroin, however, do not exhibit an increased probability of death after continued use. In any case, these results suggest that changes in the distribution of purity have important effects on specific drug use outcomes as well as the total number of ER mentions. Again using the results from Table 6, these estimates suggest that following the ADAA there would be 5 fewer cocaine deaths, 1 fewer heroin death, 200 fewer cocaine overdoses, 33 fewer heroin overdoses, 560 fewer cocaine unexpected reactions, and 86 fewer heroin unexpected reactions.

V 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. Second, I find that the introduction of this law impacted other moments of purity's distribution. Third, I show that changes in these moments impact the health outcomes of use, indicating a net health benefit from the ADAA. To the extent that Irish criminal law feeds into uncertainty over drug purity, these lessons from the US data provide useful information in fine tuning the Irish approach to illegal drugs.

[30] 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.

[31] Examples in the medical literature include Risser *et al.* (2007) who estimate the impact of average heroin purity on heroin deaths.

Table 8: *Effect of Purity Distribution on Detailed Outcomes*

	Cocaine (1) *Death*	(2) *Overdose*	(3) *Unexpected Reaction*	*Heroin* (4) *Death*	(5) *Overdose*	(6) *Unexpected Reaction*
Average Price	–0.013	–0.881*	–3.811**	–0.001*	–0.057**	0.006
	(0.010)	(0.488)	(1.450)	(0.001)	(0.027)	(0.069)
Average Purity	–0.057	–5.218**	–12.454*	–0.026	–0.138	–6.040
	(0.037)	(2.603)	(6.316)	(0.077)	(1.929)	(3.852)
CV of Purity	11.948**	1,015.766***	2,586.735***	6.489	382.691**	385.156
	(5.171)	(328.277)	(792.923)	(4.385)	(160.993)	(287.302)
Skewness of Purity	–2.050**	–170.361***	–346.498**	–1.899	–196.884***	–123.177***
:	(0.980)	(63.015)	(161.779)	(1.446)	(39.871)	(43.980)
Other controls						
Trend	–1.156**	–34.397	–46.706	–0.518	–26.674	–1.575
	(0.530)	(31.037)	(81.213)	(0.768)	(22.200)	(36.910)
Real Income	0.000**	0.025***	0.058***	0.001**	0.054***	0.030***
	(0.000)	(0.008)	(0.018)	(0.000)	(0.007)	(0.008)
Response Rate	0.022	–12.350**	–26.221	0.096	1.329	–0.675
	(0.097)	(6.188)	(17.700)	(0.114)	(3.883)	(5.803)
Constant	2,307.661**	69,509.622	94,709.202	1,017.797	51,843.623	2,598.865
	(1,055.484)	(61,747.311)	(161,564.083)	(1,529.194)	(44,141.274)	(73,509.226)
Observations	74	97	97	76	94	93
R-squared	0.186	0.240	0.188	0.109	0.464	0.157

Robust standard errors in parentheses. * significant at 10 per cent; ** significant at 5 per cent; *** significant at 1 per cent.

In closing, it is worth recognising the caveats of this study. First, it does not estimate the impact of this law on drug use.[32] Second, as with all studies on drug policy, it must be remembered that the data may not be random. If, for example, the timing of the ADAA coincided with a shift in DEA efforts towards high purity dealers in states without their own MMs, the results would represent an upper bound on the impact of MMs. Third, this paper focuses on federal MMs. Beyond this policy, there are a variety of federal and local enforcement measures that I do not directly consider. Fourth, I only consider the cocaine and heroin markets. It is likely that similar changes have occurred for other drugs.[33] Finally, it is likely that purity changes have impacted other outcomes from drug use besides ER 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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[32] 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).

[33] For example, the average THC content of marijuana rose from 1 per cent in the mid-1970s to 6 per cent in 2002 (Office of National Drug Control Policy, 2004).

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DATA APPENDIX

Four variables capture federal and state-specific law enforcement. *Budget* is the DEA's budget measured in 2000 dollars. *Agents* is the number of special agents employed by the DEA. These data are from the DEA's website.[34] One possibility is that all of these are positively correlated with purity since they are positively related to the probability of arrest. Alternatively, with more agents the DEA may be able to target more low-level dealers, leading to a drop in purity. I also include the total number of observations for a given drug (*Total Obs*) in a given year as a proxy of overall enforcement. At the state level, I include the share of a particular drug's observations in a given state in a given year (*State Intensity*). All else equal, greater relative interdiction efforts in a given location will increase its share of the total observations. Therefore, I expect this too to be positively correlated with purity. 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. If more crime leads to greater enforcement overall, purity should rise.

I include a number of state-level economic controls.[35] Economic controls include real gross state product (*GSP*) and real per-capita personal income (*Income*), both from the BEA.[36] 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 purer product. Alternatively, states with low incomes may have more users who demand higher purity.

Finally, I include several demographic variables. *Population*, obtained from the BEA, controls for state size. 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 nonwhites aged sixteen and over (*% Other Nonwhite*). Likewise, three age categories were included: *% Aged 0-17*, *% Aged 18-24*, and *% Aged 25-66*. 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-graduate*). These measure the percentage of the population for whom this is their maximum educational attainment. The percentage of the population that

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

[35] Although markets are likely segmented within a state, due to data availability I use state-level controls.

[36] These were converted into $2,000 by respectively using the GDP and personal income price deflators from the BEA.

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. I expect frequent drug users to demand a purer product, therefore, I expect higher purities in young, uneducated populations with large numbers of minorities and males.

Table A1: *Summary Statistics for Mandatory Minimum Data*

Variable	*Obs.*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Source*
Cocaine						
Purity	32,5129	59.09195	31.73785	0	100	STRIDE
Total Obs	32,5129	1628.509	1844.025	1	7213	STRIDE
State Intensity	32,5129	.1020586	.1036161	.0000576	.3628664	STRIDE
Purchase	32,5129	.3313977	.4707164	0	1	STRIDE
Heroin						
Purity	10,3568	32.0208	31.68088	0	100	STRIDE
Total Obs	10,3568	636.8365	588.127	1	2056	STRIDE
State Intensity	10,3568	.1438392	.1271989	.0001513	.4488623	STRIDE
Purchase	10,3568	.3666383	.4818889	0	1	STRIDE
State Controls						
Population	32,5129	7.86e+15	8.17e+15	3.97e+14	3.45e+16	BEA
GSP	32,5129	2.42e+11	2.57e+11	7.87e+09	1.33e+12	BEA
Income	32,5129	2.69e+10	5.61e+09	1.34e+10	4.15e+10	BEA
Agents	32,5129	3391.672	858.2553	1896	4601	DEA
Budget	32,5129	1.01e+08	3.91e+07	3.71e+07	1.66e+08	DEA
% Hispanic	32,5129	8.359309	8.033461	0	38.93061	CPS
% Black	32,5129	25.01394	23.36371	0	73.07587	CPS
% Aged 0-17	32,5129	25.38686	2.870793	14.35	39.13191	CPS
% Aged 18-24	32,5129	10.52062	1.637008	5.636529	17.36039	CPS
% Aged 25-66	32,5129	53.6531	2.597042	41.26107	61.75636	CPS
% Male	32,5129	48.32879	1.193399	43.67656	53.28239	CPS
%Female Hhold	32,5129	40.37764	9.637782	12.76664	59.65788	CPS
% High School	32,5129	23.8879	3.595519	16.39168	34.96463	CPS
%Some College	32,5129	21.03816	4.369682	11.82579	32.98914	CPS
% College	32,5129	6.256339	6.15396	0	19.01145	CPS
% Post-grad.	32,5129	7.274683	3.579499	1.564506	16.62609	CPS
Poverty Rate	32,5129	14.36207	4.183938	2.566354	29.11244	CPS
Unemp. Rate	32,5129	6.271926	1.820097	2.2	18	BLS
Crime Index	32,5129	5.15e+10	5.14e+10	1.47e+09	2.06e+11	FBI
Post State MM	32,5129	.4185846	.4933278	0	1	Author
Prior State MM	32,5129	.1179624	.3225641	0	1	Author
Federal MM	32,5129	.7772146	.4161161	0	1	Author
% Other Nonwhite	32,5129	3.431657	5.378414	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.*	*Minimum*	*Maximum*	*Source*
Cocaine						
Avg. Price	160	354.4035	1309.717	0	9911.516	STRIDE
Avg. Purity	160	40.64239	17.99777	6.75	84.66666	STRIDE
CV Purity	160	.2499911	.1502309	.0072775	.7001955	STRIDE
Skewness of Purity	160	–.7754869	.8708849	–3.173983	.9541013	STRIDE
Total Mentions	160	5223.219	4939.927	468.3386	21592.34	DAWN
Deaths	74	6.959459	6.976358	0	29	DAWN
Overdoses	97	648.5361	487.4206	43	2409	DAWN
Un. Reaction	97	1120.567	1306.197	94	5158	DAWN
Heroin						
Avg. Price	170	1851.956	5738.329	23.08582	49988.34	STRIDE
Avg. Purity	170	29.21436	14.85899	1.044444	77.75	STRIDE
CV Purity	170	.518565	.3222561	.0103227	1.709519	STRIDE
Skewness of Purity	170	.2774909	.9451136	–1.817437	2.908206	STRIDE
Total Mentions	170	2451.05	2684.242	53.17404	11332.14	DAWN
Deaths	76	9.236842	8.921687	0	37	DAWN
Overdoses	94	489.0851	383.8957	22	1569	DAWN
Un. Reaction	93	320.4731	456.9628	3	2794	DAWN
MSA controls						
Real Income	170	29853.74	4320.606	20472.13	41291	DAWN
Response Rate	170	80.27118	9.237654	44.4	100	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).