WHAT AMERICA'S USERS SPEND ON ILLEGAL DRUGS, 1988-1993

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EXECUTIVE SUMMARY

As part of an ongoing project to determine how much Americans spend on illegal drugs, this report focuses on the amount and retail sales value of cocaine, heroin, marijuana, and other illegal drugs Americans consumed from 1988 through 1993. We used two approaches to make these estimates. First, from a demand-based approach, we investigated the dollar expenditures by Americans on illicit drugs. We estimated that:

- In 1993, Americans spent $49 billion on these drugs: $31 billion on cocaine, $7 billion on heroin, $9 billion on marijuana, and $2 billion on other illegal drugs and legal drugs used illicitly (Table A).[1]

- Between 1988 and 1993, the expenditures on cocaine and heroin appear to have fallen. This trend results partly from a decrease in the number of users, but is due mostly to a decrease in the street prices of these two drugs.

- Between 1988 and 1993, the amount spent on marijuana has remained constant.

- Between 1988 and 1993, expenditures on other illicit drugs fell, as did the amount spent on legal drugs used illicitly.

A second approach to estimating the retail sales value of illicit drugs consumed in the United States is to estimate the amounts of drugs supplied to the domestic market. From this supply-based perspective, we estimate that:

- A high-range estimate of 340 metric tons of cocaine were available for domestic consumption in 1993 (see Table B).[2] Between 1988 and 1993, the amount of cocaine available for consumption in the United States remained at a fairly constant level. But because of declining prices, the street value of that cocaine has fallen over time.

- The street value of domestically available cocaine is from $33 to $46 billion (Table B).[3] Between 1988 and 1993, Americans spent from $33 billion to $90 billion, annually, on cocaine.

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[1] Money is not the only form of payment for illicit drugs. Dealers often keep drugs for personal use, users help dealers in exchange for drugs, and users perform sex for drugs (especially crack cocaine). When such "income in kind" is valued at current retail prices, an additional $3 billion to $5 billion must be added to the total for cocaine and an additional $2 billion to $3 billion to the total for heroin. In this report, all expenditures are in 1994 dollar equivalents. These expenditure estimates do not include income in kind.

[2] Between 581 and 711 metric tons of cocaine hydrochloride were available for export during 1993. To arrive at the total available for domestic consumption, we subtracted from this amount losses in shipment, shipments to other consumer countries, and Federal seizures.

[3] Prevailing retail prices are used to convert drug supply to a dollar equivalent value when sold to final users.

It should be noted that the range for cocaine expenditures derived from the supply model is larger than the consumption-based expenditure estimates (Table A). There are two reasons for this. First, the supply model does not take into account most losses and consumption within the producer countries or State and local seizures in this country. Second, the United States may transship more drugs to Europe than our model assumes. Had we been able to account for these factors, the $33 billion to $90 billion supply-based estimate (Table B) would have been lower. Still, the estimates based on drug consumption are remarkably close to those based on drug supply.

Although the estimates provided in this paper are somewhat imprecise, they are sufficiently reliable to conclude that, according to consumption-based estimates (Table A),[4] the trade in illicit substances ranged from $49 billion to $66 billion between 1988 and 1993. However, the costs to society from drug consumption far exceed this amount. Drug use fosters crime; facilitates the spread of catastrophic health problems, such as hepatitis, endocarditis, and AIDS; and disrupts personal, familial, and legitimate economic relationships. The public bears much of the burden of these indirect costs because it finances the criminal justice response to drug-related crime, a public drug-treatment system, and anti-drug prevention programs.

The importance of these estimates is not that they provide an accurate accounting of the retail sales from illicit drugs and from legal drugs used illegally. The estimates have an appreciable margin of error, and it seems unnecessary to have a study that says that the illicit drug trade is immense. Public officials already know that.

Although the estimate of retail sales is interesting, the greatest value of the exercise described in this report is that it forces an integration of sometimes disparate data sources into a composite view of drug use trends in America. For example, the Drug Abuse Warning Network (DAWN) reports 102,000 emergency room admissions in 1988; 80,000 in 1990; and a preliminary estimate of 123,000 in 1993.[5] Do these data imply that cocaine use has increased over the past six years?

Perhaps it has, but other indicators suggest otherwise. According to the National Household Survey on Drug Abuse (NHSDA), the number of people who use cocaine on a weekly basis fell from 884,000 in 1988 to 642,000 in 1993. Best estimates based on the Drug Use Forecasting (DUF) data suggest that there were about 2.1 million hardcore cocaine users in 1988 (another 200,000 were incarcerated) and about 1.9 million in 1993 (another 400,000 were incarcerated). In contrast to DAWN, these estimates suggest that the number of hardcore cocaine users has remained fairly constant over the last six years.

Furthermore, the crop production estimates presented in this report strongly imply that the amount of cocaine available for consumption has not changed much over time. Of course, this is consistent with the observations that the number of hardcore users has remained fairly constant. Otherwise, we would expect cocaine prices to have risen as increased demand put pressure on a constant supply. This has not happened.

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[4] By comparison, Americans spent about $43 billion on tobacco in 1993. The Tobacco Institute , *The Tax Burden on Tobacco* (Washington, D.C.; 1993).

[5] Substance Abuse and Mental Health Services Administration, Office of Applied Studies, *Preliminary Estimates from the Drug Abuse Warning Network: 1993 Preliminary Estimates of Drug-Related Emergency Department Episodes*, Advance Report Number 8 (Rockville, MD; October 1994).

Indeed, cocaine prices have fallen from roughly $290 per pure gram in 1988 to $240 per pure gram in 1993. This decrease might be attributed to the small decrease in the number of hardcore users and to a large decrease in the number of occasional users. (According to the National Household Survey on Drug Abuse, the number of occasional users fell from about 7.3 million in 1988 to about 4.0 million in 1993.)

Putting these data together provides a mosaic of drug use trends in America. It allows us to see that data from the State Department (crop data), the Drug Enforcement Administration (price data), the Substance Abuse and Mental Health Administration (household survey data), and the Department of Justice (arrestee drug testing data) provide a consistent picture of major drug use trends. Of equal importance, it forces us to question our interpretation of other data, such as the Drug Abuse Warning Network, enabling us to better integrate these data into the mosaic.

TABLE A

Total U.S. Expenditures on Illicit Drugs, 1988–1993
($ in billions, 1994 dollar equivalents)

	1988	1989	1990	1991	1992	1993
Cocaine	$41.1	$42.5	$38.9	$35.2	$33.1	$30.8
Heroin	$11.2	$11.5	$10.3	$8.2	$7.0	$7.1
Marijuana	$8.9	$9.0	$9.6	$9.0	$10.1	$9.0
Other Drugs	$3.2	$2.8	$2.3	$2.4	$2.2	$1.8
Total	$64.4	$65.8	$61.1	$54.8	$52.4	$48.7

Note: Columns may not add due to rounding.
Source: See Tables 1 through 8

TABLE B

Trends in the Cocaine Supply, 1989-1993
(in metric tons unless otherwise noted)

	1989	1990	1991	1992	1993
Cocaine HCl available for export from producing countries[1]	708–857	705–858	748–941	771–989	581–711
Cocaine destined for the United States	531–643	529–643	561–705	578–742	436–533
Foreign seizures of cocaine destined for the United States[2]	55	85	96	83	82
Cocaine shipped to the United States	476–588	444–559	465–609	495–659	353–450
Federal Seizures[3]	115	96	128	120	110
Cocaine available for consumption in the United States	361–473	348–463	337–481	376–539	243–340
Retail value of cocaine in the United States (in billions of dollars)	$52–68	$67–90	$51–72	$55–79	$33–46

[1] Estimates of cocaine HCl come from the computer model of cocaine production. The range is based on the error band reported by the Department of State for the area under cultivation.

[2] Bureau of International Narcotics Matters, *International Narcotics Control Strategy Report* (Washington, D.C.: Department of State Publication, April 1994 and previous years); Royal Canadian Mounted Police (RCMP), *National Drug Intelligence Estimate, 1994* (and previous years) and International Narcotics Control Board, Narcotic Drugs Statistic for 1991 (and previous years).

[3] Drug Enforcement Administration, Federal-wide Drug Seizure System, 1989–1993.

WHAT AMERICA'S USERS SPEND ON ILLEGAL DRUGS

In 1993, the Office of National Drug Control Policy (ONDCP), working with Abt Associates Inc., reported that Americans spent an estimated $45 billion to $51 billion a year between 1988 and 1991 for illicit drugs and for licit drugs used illegally. New data and a revised methodology have enabled us to improve those estimates and to extend them through 1993.

To estimate the retail sales value of illicit drugs consumed in the United States, we examined both the demand for and the supply of drugs. The demand or *consumption approach* estimates the number of drug users, how much they spend on drugs, and the amount of drugs they consume. The *supply* approach estimates the volume of drugs available for consumption. To determine the amount of drugs available in this country and the retail value of these drugs, we estimated the amount of base crop raised in producer countries, and reduced it by the amounts lost, seized, or consumed in other countries and by the amount seized in or shipped through the United States to other countries. We then multiplied the result by retail prices.

For a number of reasons, neither of these approaches yields precise estimates of the yearly retail value of the illegal drug trade. First, the secretive nature of drug crop production and manufacturing prevents accurate assessments of drug production. Second, with some exceptions, drug dealers and their customers transact business away from public view. Finally, drug users often misrepresent their drug use when interviewed. Thus, estimates of retail expenditures must be based on incomplete, inaccurate, and often inconsistent data, as well as assumptions that occasionally lack strong justification.

Therefore, we encourage an evaluation of our findings in three ways. First, the reader can compare our estimates with those reported elsewhere. Second, the reader should also consider whether or not the two independent approaches used in this report (supply-based and demand-based) reach similar conclusions about the amount American drug users spend on drugs. Finally, our calculations can be replicated using alternative assumptions the reader finds more plausible than the ones we used.

The report is divided into three sections. Section I reports estimates derived using the consumption approach. Section II reports estimates for cocaine derived from a supply approach. Section III summarizes and reconciles the differences between the two approaches. Technical material appears in appendices.

1. CONSUMPTION APPROACH

COCAINE AND HEROIN

Between 1988 and 1993, American users spent $31 billion to $41 billion yearly on cocaine and $7 billion to $12 billion yearly on heroin. To arrive at these estimates, we multiplied the number of users by their average expenditures, and then converted the resulting estimates to 1994 dollar equivalents.

The number of cocaine and heroin users

The National Household Survey on Drug Abuse (NHSDA), the Nation's most comprehensive survey of drug use, measures drug use among the American household population age 12 and older, as well as people living in group quarters and the homeless.[6] The NHSDA misses a part of the population that may be a key to determining the extent of drug use: those who, although not homeless, are too unstable to be considered as part of a household, or who, if part of the household, are unlikely to answer surveys.[7]

This less-stable population is, however, well represented in data collected by the Drug Use Forecasting (DUF) program, which questions a random sample of arrestees in 24 central city jails and lockups about their drug use.[8] DUF also asks arrestees to voluntarily produce samples for urinalysis. This

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[6] The NHSDA excludes military personnel, those incarcerated in jails and prisons, and those who are residents of treatment facilities. Military personnel, whose consumption of illicit substances is monitored through urinalysis, do not have the opportunity to be heavy drug users. Those incarcerated in jails and lockups may use drugs, but that consumption must necessarily be limited by restricted availability. Sources at the National Institute on Drug Abuse consider drug use by those in residential treatment facilities to be minimal.

[7] Evidence that a large segment of the drug-using population is excluded from the NHSDA comes from a number of sources. According to the 1991 NHSDA, drug use is twice as high among respondents who lived in households considered unstable than it is among those who lived in more stable environments, indicating that the NHSDA's bias toward reporting on stable households is likely to miss many heavy drug users. Available evidence indicates that NHSDA's numbers understate heavy drug use. A. Harrell, K. Kapsak, J. Cisin, and P. Wirtz, "The Validity of Self-Reported Drug Use Data. The Accuracy of Responses on Confidential Self-Administered Answer Sheets," paper prepared for the National Institute on Drug Abuse, Contract Number 271-85-8305, December 1986.

Consistent with these observations, the Substance Abuse Mental Health and Services Administration reports that virtually no heroin addicts answer the National Household Survey on Drug Abuse. Substance Abuse Mental Health and Services Administration, *Preliminary Estimates from the 1993 National Household Survey on Drug Abuse* (June 1994).

Additional evidence also comes from interviews with nearly 35,000 intravenous drug users who were contacted by National Institute on Drug Abuse-sponsored researchers as part of an AIDS outreach project. Abt Associates' tabulations show that an estimated 40 percent of these drug users lived in unstable households and about 10 percent could be considered homeless.

Finally, a comparison of the demographic characteristics of the heavy cocaine users in the NHSDA with those of heavy cocaine users based on other sources (the Drug Use Forecasting program, the Drug Abuse Warning Network, and the National AIDS Demonstration Research project) shows a marked difference in populations. Incomes are greater, unemployment is lower, and there are fewer respondents using more than one drug in the NHSDA population. D. Hunt and W. Rhodes, "Characteristics of Heavy Cocaine Users Including Polydrug Use, Criminal Behavior, and Health Risks," paper prepared for Office of National Drug Control Policy (ONDCP), December 14, 1992.

[8] A large percentage of heavy drug users are arrested at some time in their drug-using "careers," so the criminal justice system provides valuable supplemental data when counting heavy drug users. For example, in the 1993 Household Survey, about 58 percent of the heavy cocaine users surveyed had been arrested and booked at some time, 39 percent during the year prior to the survey. In the National AIDS Demonstration Research data, 81 percent of heavy cocaine users had been arrested at some time in their lives, and one-third had been in jail or prison during the six months prior to the interview.

helps to confirm whether the interviewees have used up to 10 types of drugs during the two to three days before the interview. Although urinalysis is subject to error and tells us nothing about the frequency of drug use, it adds credence to estimates of drug use when self-reports are unreliable.

The hardcore user is identified in the NHSDA as one who used cocaine at least one or two days a week every week during the year before the survey, or one who used heroin on more than 10 days during the month before the survey. In this analysis, hardcore users in the DUF data are defined as those who admitted using cocaine or heroin on more than 10 days during the month before being arrested.[9]

Occasional users are identified in the NHSDA as those whose drug use was less frequent than the hardcore drug use criteria described above. Occasional use cannot be estimated from DUF.[10]

Table 1 provides estimates of the number of hardcore and occasional cocaine and heroin users derived from the NHSDA and the DUF data.[11] (Drug users who use other drugs will be discussed later.) Note that because the NHSDA was not administered in 1989, the 1989 NHSDA estimates used in this report are the average of 1988 and 1990 data. To obtain a composite estimate, we added estimates from

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[9] Hardcore users consume illicit drugs at least on a weekly basis and exhibit behavioral problems stemming from their drug use. Hardcore users cannot be identified precisely from available data. Using DUF data, a hardcore users is one who used illicit drugs on ten or more days per month. Behavioral problems are implied by the fact that such users have all been arrested at least once. Also, 57 percent of such cocaine users and 77 percent of such heroin users deemed themselves to be in need of treatment. These self-reports probably understate the need for treatment, because denial of the need for treatment is high among hardcore users. Thus, the vast majority of arrestees who admit to using cocaine or heroin on ten or more days during the previous month are hardcore users according to the definition used here. Using NHSDA data, a hardcore user is one who used cocaine on a weekly basis. Behavioral problems are implied by the fact that almost sixty percent of weekly users in the 1993 NHSDA had been arrested and booked at some time.

[10] Because urinalysis will detect cocaine and heroin use within two to three days of its consumption, it is unlikely that urinalysis will fail to identify an individual who uses cocaine on at least a weekly basis. (Most weekly users use it more frequently than once a week.) However, an occasional user is likely not to have used cocaine or heroin within two to three days of his or her arrest. Consequently, DUF would frequently fail to identify occasional users. Arguably, the EMIT test used by DUF understates drugs in the urine of arrestees. C. Visher and K. McFadden, *A Comparison of Urinalysis Technologies for Drug Testing in Criminal Justice*, NCJ-129292, June 1991. However, it seems reasonable that occasional users are more likely than hardcore users to have an erroneous negative urine test, so we have not adjusted the DUF urine test results to reflect the EMIT test's false negative rate of about 20 percent. For evidence supporting this decision, see T. Mieczkowski, "Immunochemical Hair Assays, Urinalysis, Self Reported Use and the Measurement of Arrestee Cocaine and Marijuana Exposure in a Large Sample," paper presented at the Annual Meetings, American Society of Criminology, New Orleans, November 7-22, 1992.

[11] Methods used to convert the DUF data into estimates of hardcore drug users throughout the criminal justice system have been described in W. Rhodes, "Synthetic Estimation Applied to the Prevalence of Drug Use," *Journal of Drug Issues*, 23, no. 2 (1993):297-321. To summarize, the DUF program is not a probability sample of arrestees, so a weighting scheme was used to derive an estimate of the percentage of arrestees who would be expected to test positive in each of the DUF sites. The DUF sites overrepresent large city lockups, so a mathematical model was used to infer the percentage of arrestees who would have tested positive in non-DUF sites if DUF programs had operated in those sites. There is an unknown number of active drug users who run more than a negligible risk of being arrested at some time between the first and last times they used drugs - that is, during their drug use careers. The DUF data provide estimates of the number who were arrested during a given year. A mathematical model, based on a truncated Poisson process, then provides estimates of the number who were at risk of being arrested during that year. An estimate of that at-risk group, those who are "involved with the criminal justice system," is reported here. These figures do not include hardcore users who are incarcerated. A Bureau of Justice Statistics study reports "In State correctional facilities, 3.6 percent of the tests for cocaine, 1.3 percent for heroin, 2.0 percent for methamphetamine, and 6.3 percent for marijuana found evidence of drug use. In Federal prisons, 0.4 percent of the tests for cocaine, 0.4 percent for heroin, 0.1 percent for methamphetamine, and 1.1 percent for marijuana were positive." C. Harlow, *Drug Enforcement and Treatment in Prison, 1990 (NCJ-134724, July 1992)*. These percentages are probably high because tests are most likely to be conducted when drug use is suspected. In any case, drug use in prisons cannot account for much of the drug use that occurs in America.

DUF to the estimates from the NHSDA, and then subtracted the overlap.[12] The result shows that between 1988 and 1993, there were about 2.1 million to 2.6 million Americans who were hardcore users of cocaine and approximately 4.0 million to 7.3 million who were occasional users. Another 444,000 to 607,000 Americans were hardcore users of heroin, and 229,000 to 539,000 were occasional users.[13] Although imprecise, these estimates are consistent with reported estimates derived by others using different methodologies and data.[14] A separate analysis, which appears in Appendix 1, also supports these estimates.

[12] DUF data are used to produce estimates of the number of adult heavy users who are at risk of arrest during a given year. However, some hardcore drug users manage to avoid criminal justice involvement, perhaps because their drug purchases are discreet and their consumption is private. Also, juveniles who are hardcore users are not reflected in DUF. When deriving a composite figure, only the percentage of adults who avoided the criminal justice system and juveniles are counted in the hardcore use category of the NHSDA. The remainder are assumed to have already been included in the DUF hardcore user tally. For the years 1988 through 1993, the percentages of NHSDA respondents who were included in our estimates of heavy users were 58 percent, 60 percent, 62 percent, 56 percent, 63 percent, and 42 percent respectively. These percentages were based on arrest histories as reported in the NHSDA.

The resulting estimate of the number of hardcore users represented in the NHSDA, but not in DUF is certainly too large. Many people who were not arrested in the year before their interview were still *at risk* of being arrested, and hence, represented in DUF. A more conservative estimate would make little difference in the final estimates reported in Table 1, however, because the residual number of users from the NHSDA is already small relative to the estimate from DUF.

[13] A large number of drug users use both heroin and cocaine. For example, 23 percent of the hardcore cocaine users in the 1993 DUF sample are current heroin users, and 12 percent of them use heroin daily.

[14] Hamill and Cooley estimated 640,000 to 1.1 million heroin addicts in 1987. D. Hamill and P. Cooley, *National Estimates of Heroin Prevalence 1980-1987: Results from Analysis of DAWN Emergency Room Data* (RTI Report, Triangle Park, N.C.: Research Triangle Institute, 1990).

TABLE 1

Estimated Number of Hardcore and Occasional Users of Cocaine and Heroin, 1988-1993

	1988*	1989*	1990*	1991	1992	1993
NHSDA						
Cocaine						
Hardcore	884,148	776,765	668,328	625,000	624,785	642,222
Occasional	7,347,000	6,465,843	5,584,686	5,440,415	4,330,521	4,054,117
Heroin						
Hardcore	23,565	23,565	23,565	23,565	23,565	23,565
Occasional	539,000	504,446	469,891	368,102	289,557	229,251
DUF						
Cocaine						
Hardcore	2,129,847	2,210,379	2,051,321	1,865,858	1,913,496	1,922,578
Heroin						
Hardcore	590,104	605,161	531,745	463,184	441,073	489,240
COMPOSITE						
Cocaine						
Hardcore	2,540,525	2,624,312	2,468,509	2,218,700	2,339,381	2,127,166
Occasional	7,347,000	6,465,843	5,584,686	5,440,415	4,330,521	4,054,117
Heroin						
Hardcore	591,990	607,046	533,630	465,305	444,372	496,309
Occasional	539,000	504,446	469,891	368,102	289,557	229,251

* The NHSDA estimates of cocaine users is adjusted for 1988 and 1990 to account for the survey's limited coverage during those years. The adjustment adds an estimate of hardcore drug users who live in college dormitories to the estimate of hardcore users derived from the NHSDA. Students living in college dormitories are represented in the 1991 and later NHSDA. The NHSDA was not administered in 1989. Estimates for 1989 are the averages for 1988 and 1990.

Sources: NHSDA 1988, 1990 through 1993; DUF 1988 through 1993; Uniform Crime Reports (UCR) 1988 through 1993.

Average amount spent on cocaine and heroin

The 1989 and later DUF interviews asked respondents how much they spent on drugs during a week. The question did not separate cocaine from heroin spending or exclude other drugs, so we must distinguish between how much was spent on cocaine and how much was spent on heroin. Also, some

respondents gave answers that were implausibly large,[15] so based on the methodology explained in Appendix 2, we adjusted estimates to moderate the effect of extreme values.

Hardcore cocaine users spent more than $220 a week on cocaine and hardcore heroin users spent just over $250 a week on heroin in 1993 (Table 2).[16] These DUF estimates lack precision, but they are reasonable considering other data about expenditures on illicit drugs (see Appendix 2).

Several studies provided estimates consistent with ours.[17] A few others, however, reported drug expenditures that were much higher.[18] Many of these latter studies, however, were derived from samples of people who had just entered treatment. Because people often enter treatment when their habits have become too expensive, these individuals may be at the peak of their drug use, which is higher than that of most hardcore users.

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[15] For example, there are physiological limits to drug consumption. Given the duration of a single administration of heroin, it is unnecessary to shoot heroin more often than four times a day, every day. Given New York State Division of Substance Abuse Services approximations of typical drug use, it seems unlikely that a heavy user would spend any more than $420 per week, and even this would be an extremely high level of consumption (New York State Division of Substance Abuse Services, Memorandum, n.d.).

Cocaine use triggers the desire for more of the drug. Binge use exhausts the body, so rest is necessary before another binge. Also, heavy cocaine use can quickly exhaust a user's financial resources. Except for the rare cocaine user, expenditures greater than those assumed here are unlikely.

[16] These estimates are median values; mean values are about twice as large. However, the median expenditure seemed more justifiable given other studies of drug expenditure patterns. See Appendix 2.

[17] Johnson and Wish surveyed property criminals in 1983 and estimated their weekly expenditures on cocaine to be $203 and expenditures on heroin to be $203. Reuter, et al. interviewed a sample charged with selling drugs in Washington, D.C. from 1985 to 1987. They estimated median weekly expenditures on illicit drugs at $100. However, Reuter's sample included users who did not use drugs heavily, so his estimate is expected to be lower than ours. Johnson and colleagues surveyed about 200 heroin users who lived on the streets of Harlem and who had engaged in property or drug crimes. They estimated the dollar value of drugs used per week at $250. Mieczkowski appended queries to the DUF questionnaire administered in Detroit and determined a median weekly expenditure on crack of $150. B. Johnson and E. Wish, "The Robbery-Hard Drug Connection: Do Robbers and Robberies Influence Criminal Returns and Cocaine-Heroin Purchases?", paper presented at the Criminology Section of the American Sociological Association, August 17, 1987; P. Reuter et al., *Money from Crime: A Study of the Economics of Drug Dealing in Washington, D.C.* (Santa Monica, California: RAND Corporation, 1990), RAND publication R-3894-RF; B. Johnson et al., *Taking Care of Business: The Economics of Crime by Heroin Abusers* (Lexington, Massachusetts: Lexington Books, 1985); T. Mieczkowski, "Crack Distribution in Detroit," *Contemporary Drug Problems*, (Spring 1990): 9.

[18] All of the highest estimates come from estimations of former use by patients in drug treatment; this group may represent the heaviest users in the country. Using a sample drawn from Detroit drug treatment programs from 1987 through 1989, Mieczkowski estimated prior weekly expenditures on crack at a median of $600. Schnoll and colleagues reported a weekly expenditure of $800 per week on cocaine in a Chicago treatment population. Gawin and Kleber described a New Haven treatment population whose weekly expenditures on cocaine would have been between $500 and $900, applying Abt Associates' estimates for the price of cocaine to reported consumption patterns. Collins, Hubbard and Rachal estimated that heavy heroin users spent $4,000 to $10,000 per year, and heavy cocaine users spent $6,000 to $14,00 per year. All had entered treatment in 1979. T. Mieczkowski, "The Economic Dimensions of Crack Use and Distribution: Some Preliminary Data," paper presented to the American Society of Criminology Annual Meeting, Reno, Nevada, November 1989; S. Schnoll et al., "Characteristics of Cocaine Abusers Presenting for Treatment," in *Cocaine Use in America: Epidemiological and Chemical Perspectives*, ed. N. Kozel and E. Adams (Rockville, Maryland: National Institute on Drug Abuse, 1985), NIDA Research Monograph 61, 171-181; F. Gawin and H. Kleber, "Cocaine Use in a Treatment Population: Patterns and Diagnostic Distinctions," in *Cocaine Use in America: Epidemiological and Chemical Perspectives*, ed. N. Kozel and E. Adams, (Rockville, MD: National Institute on Drug Abuse, 1985), NIDA Research Monograph 61, 182-192. J. Collins, R. Hubbard, and J. Rachal, "Expensive Drug Use and Illegal Income: A Test of Explanatory Hypotheses," *Criminology* 23, no. 4 (1985): 743-763.

Of course, occasional users spend less per week than do hardcore users. Based on NHSDA data, occasional cocaine users spent $19 in 1988, $23 in 1989, $27 in 1990, $30 in 1991, $34 in 1992, and $35 in 1993. No such estimates are available from the NHSDA for occasional heroin users. For them, we assumed a weekly expenditure that was one-fifth of the amount spent by hardcore users, or $50 to $63 per week.

TABLE 2

Weekly Median Cocaine and Heroin Expenditures Reported by Arrestees, 1989-1993 (dollars, 1994 dollar equivalents)

	1989	1990	1991	1992	1993
Cocaine					
Hardcore use	$276	$265	$251	$231	$221
Heroin					
Hardcore use	$312	$316	$291	$206	$251

Source: DUF 1989 through 1993.

Total expenditures on cocaine and heroin

Between 1988 and 1993, American users spent $31 billion to $41 billion yearly on cocaine and $7 billion to $12 billion yearly on heroin (Table 3). We derived these estimates by multiplying the number of hardcore and occasional users in Table 1 by the expenditures in Table 2 (after eliminating the overlap) and adding results.[19]

[19] See footnote 12.

TABLE 3

Total Expenditures on Cocaine and Heroin, 1988-1993
($ in billions, 1994 dollar equivalents)

	1988*	1989	1990	1991	1992	1993
Cocaine Expenditures						
Hardcore users	$33.8	$34.7	$31.1	$26.7	$25.5	$23.3
Occasional users	$7.3	$7.7	$7.8	$8.5	$7.6	$7.5
Total users	$41.1	$42.5	$38.9	$35.2	$33.1	$30.8
Heroin Expenditures						
Hardcore users	$9.5	$9.9	$8.8	$7.1	$6.2	$6.5
Occasional users	$1.7	$1.6	$1.5	$1.1	$0.8	$0.6
Total users	$11.2	$11.5	$10.3	$8.2	$7.0	$7.1

* Since weekly expenditures from DUF data were not available for 1988, we used the 1989 amounts as proxies for 1988 in calculating total expenditures.

Source: See Tables 1 and 2.

How the estimates are affected by varying the assumptions

The estimates of expenditures may vary due to assumptions made about the number of hardcore and occasional users and about their average expenditures.[20] Because hardcore users account for the bulk of drug spending,[21] our estimates of total expenditures are especially sensitive to the accuracy of estimates about expenditures by hardcore users. Consequently, we tested how sensitive our expenditure estimates are to assumptions made about the number of hardcore users and their typical expenditures.

First, we determined how the expenditure estimates would be affected if we used lower or higher estimates of the number of users than we reported in Table 1. Based on a review of published literature and on additional tests on the data, we estimated that there are between 1.5 million and 2.5 million hardcore users of cocaine and between 400,000 and 800,000 hardcore users of heroin in America.[22] Because the retail sales estimates are roughly proportional to the number of hardcore users, if the estimate

[20] Because the factors that entered the calculations were not derived from probability samples, it is impractical to develop a statistically based margin of error.

[21] Heavy cocaine users represent less than one-fourth of the total number of cocaine users, but they account for 79 percent of all cocaine expenditures. Apparently because of heroin's stigma, casual use of heroin is less frequent than casual use of cocaine. Consequently, heavy users account for the bulk of that market--87 percent of all heroin expenditures.

[22] That is, the true number of heavy cocaine and heroin users would seem to fall within these ranges. See W. Rhodes, "Synthetic Estimation Applied to the Prevalence of Drug Use," *Journal of Drug Issues*, 23, no. 2 (1993):297-321.

of hardcore users is off by plus or minus 25 percent, then the retail sales estimates would be off by the same proportion.[23]

Second, we determined how the expenditure estimates would be affected if we varied our assumption about average expenditures. As noted earlier, some studies are based on reports of expenditures by cocaine users entering treatment. If these expenditures were considered typical, the retail sales value of cocaine would be four times the amount reported here. This seems an implausibly large expenditure that would exceed not only available income for most users, but the value of the supply of the drugs as well.[24] (For a further discussion of this topic, see Appendix 2.)

Although an average expenditure figure based on a treatment population is certainly too high, it might be realistic to adopt the average (rather than the median) drug spending numbers reported by DUF as a high estimate. Then, the composite totals on both cocaine and heroin use would be twice as high as reported in Table 3. For the reasons we cited above, it is doubtful that expenditures in the United States approach this high estimate.

At the opposite extreme, hardcore users who report their use in the NHSDA appear to consume less than half as much cocaine as hardcore users represented in the DUF data. Their expenditures might be considered a low estimate of typical cocaine spending by hardcore users. Giving more weight to the NHSDA expenditure figures would reduce the amount reported in Table 3 by half. However, it is difficult to reconcile estimates that are half as large with the amount of heroin and cocaine that enters the country.

In sum, it seems plausible that cocaine and heroin expenditures could be twice as large or half as large as our estimates. But, for the reasons noted above, high- and low-end estimates should be discounted. In addition, other analysts have made clever use of available data to derive their own

[23] Some might argue that the margin of error should be even greater because the estimate of spending by heavy drug users is not precise and because some studies report much higher spending levels than those reported here.

[24] Two factors make the assumption of higher spending questionable. First, incomes of most drug users cannot support a higher level of drug use. Second, heavy drug users have a high level of unemployment and underemployment. D. Hunt and W. Rhodes, "Characteristics of Heavy Cocaine Users, Including Polydrug Use, Criminal Activity and Health Risks," paper prepared for ONDCP, December 14, 1992. As discussed in the appendix, illegal income from property crimes and prostitution accounts for much of the expenditure on drug use. However, illegal income cannot account for higher expenditures than are reported in this study. Drug dealing is often advanced as a way to support hardcore drug use, but in total, street-level dealing cannot generate the dollars that ultimately must go to satisfy the cash demands of middle-level and upper-level dealers. If expenditures are much greater than reported here, the income source for supporting that level of consumption is suspect.

estimates of retail expenditures on cocaine and heroin. After adjusting for the limitations of these other studies, our estimates are consistent with theirs.[25]

Accounting for income in kind

Our expenditure estimates reflect money that actually changed hands at the retail level. But drugs are often obtained as "income in kind," sometimes as payment for serving a role in the distribution chain and sometimes as payment for sex. For reasons explained in Appendix 2, we assume that hardcore users of heroin received 22 percent of their drugs as in-kind payment and that users of cocaine received half that amount.

If we add in-kind payments to street prices, then the dollar expenditure on cocaine would increase by between $3 billion and $5 billion, and the dollar expenditure on heroin would increased by between $2 billion and $3 billion. These totals are not reflected in Table 3, but we do take them into account later when we estimate the bulk amounts of cocaine and heroin used in America.

How much cocaine and heroin is consumed?

To estimate how much cocaine and heroin Americans consume, we used data from the System to Retrieve Drug Evidence (STRIDE) to estimate the street prices paid for cocaine and heroin.[26] The price varies with the size of the purchase lot. Cocaine is much less expensive when bought as a large lot than when purchased as a smaller lot. This is also true of heroin.

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[25] Reuter and Kleiman estimated that the market for cocaine was about $8 billion in 1982. Because of the accelerating use of cocaine from that time until the mid-1980s and after accounting for inflation, it is not surprising that their estimate is less than the figure reported here. Their $8 billion estimate for heroin expenditures is more difficult to reconcile with what is reported here for two reasons. First, the number of heroin users has not fallen much over the last decade. Second, the price of heroin has dropped dramatically. We would expect their estimates to be greater than those reported here, but that is not the case. P. Reuter and M. Kleiman, "Risks and Prices: An Economic Analysis of Drug Enforcement," in *Crime and Justice: An Annual Review of Research*, volume 7, ed. M. Tonry and N. Morris (Chicago: University of Chicago Press, 1986), 194. Carlson, who conducted a study of the underground economy for the Internal Revenue Service, reported that an estimated $11 billion was spent on cocaine in 1982. K. Carlson et al., "Unreported Taxable Income for Selected Illegal Activities: Volume I: Consensual Crimes," paper prepared for the Internal Revenue Service under contract number TIR-81.57, September 1984. In an update of his study, Carlson estimated that cocaine expenditures increased from $5.8 to $6.6 billion between 1988 and 1991. K. Carlson, "Unreported Illegal Source Income 1983-1995," paper prepared for the Internal Revenue Service under order number 89-11565, May 15, 1990. Since he relied heavily on the NHSDA, and because his estimates are not adjusted for inflation, it is not surprising that his estimate is much lower than the one reported here. Carlson's estimate of heroin expenditures, based on the National Narcotics Intelligence Consumers Committee estimates for 1982, was in keeping with Reuter and Kleiman's $8 billion figure. His updated study, based on NHSDA data, put that figure at roughly $7 billion a year between 1988 and 1991. Thus, his estimates are consistent with those reported here.

[26] These data come from laboratory analyses of purchases by Drug Enforcement Administration agents, other Federal agents, and some State and local agents.

TABLE 4

Retail Prices Per Pure Gram for Cocaine and Heroin, 1988-1993
(dollars, 1994 dollar equivalents)

	1988	1989	1990	1991	1992	1993
Cocaine						
High Price	$186	$165	$200	$168	$163	$151
Low Price	$146	$123	$187	$132	$130	$120
Heroin						
High Price	$3,007	$2,713	$2,199	$2,543	$2,614	$2,553
Low Price	$1,612	$1,343	$997	$1,046	$966	$837

Source: STRIDE 1981 through 1993.

Unfortunately, there are no good estimates of the amount of cocaine and heroin typically transacted at the retail level, but it appears that transaction sizes often exceed single doses. Given this uncertainty, we assume two price series each for cocaine and heroin. Appendix 3 justifies these choices.

Results based on statistical analysis used to estimate these prices between 1988 and 1993 are reported in Table 4. The price of cocaine fell throughout the early 1980s and reached a low point in late 1988 or in early 1989. It increased during 1990, and then declined again in 1991 and into 1993. The price of heroin also fell throughout most of the 1980s, reached a low point sometime late in that decade, and since then, has remained relatively constant (with minor fluctuations) (Table 4).

Table 5 shows estimates of the amount of cocaine and heroin that was consumed based on the expenditures reported in Table 3 (adjusted to account for drugs earned as income in kind)[27] and the retail prices reported in Table 4. According to the data for the 1988 to 1993 period, cocaine users consumed somewhere between 215 and 382 metric tons of pure cocaine each year. Heroin users consumed between 4 and 13 metric tons of pure heroin each year during the same period.

[27] In-kind expenditures (in billions) for cocaine were estimated at $4.5 in 1988, $4.6 in 1989, $4.1 in 1990, $3.6 in 1991, $3.4 in 1992, and $3.2 in 1993. For heroin, in-kind expenditures were estimated at $3.3 in 1988, $3.5 in 1989, $3.1 in 1990, $2.5 in 1991, $2.2 in 1992, and $2.2 in 1993.

TABLE 5

Total Amount of Cocaine and Heroin Used, 1988-1993
(in metric tons)

	1988	1989	1990	1991	1992	1993
Cocaine						
High Price	244	286	215	230	224	224
Low Price	311	382	230	293	280	283
Heroin						
High Price	5	5	6	4	3	4
Low Price	9	11	13	10	9	11

Source: See Tables 1 through 4.

Because the retail prices in Table 4 are not totally accurate, trends are uncertain. However, it appears that the amount of money spent per user on cocaine and heroin has fluctuated very little over the last six years. The bulk amount of cocaine used decreased in 1990, apparently in response to a significant price increase that year. Consumption increased thereafter.

The amount of heroin used seems to have decreased over time, but it is hard to be sure because of the wide ranges involved in these estimates. As already noted, there seem to be fewer heroin addicts in 1993 than there were in 1988. The HIV virus and AIDS have taken a toll.[28] Yet, prices have fallen so much that remaining users may be able to purchase much more than they did in the past.

MARIJUANA

In this section, we estimate the dollar value of marijuana consumption by multiplying the following factors: number of users in the past month, by the average number of joints used in the past month, by the average weight per joint, by the cost per ounce. Calculations are summarized in Table 6.

[28] As of June 1994, 105,335 cases of AIDS (78%) were attributed to injection drug use or to injection drug use plus some other mode of exposure. Centers for Disease Control and Prevention, HIV/AIDS Surveillance Report, 6, no.1 (1994): 16.

TABLE 6

Calculation of Total Marijuana Consumption, 1988-1993

	1988	1989	1990	1991	1992	1993
Numbers of Users (millions)	11.6	10.9	10.2	9.7	9.0	9.0
Joints used per month	16.9	17.3	17.6	16.6	17.2	17.8
Weight of a joint (ounces)	0.0134	0.0135	0.0137	0.0135	0.0134	0.0136
Price per ounce, 1/3 ounce purchase	$281.2	$291.4	$323.4	$343.1	$460.6	$341.7
Total expenditure ($ in billions, 1994 dollar equivalents)	$8.9	$9.0	$9.6	$9.0	$10.1	$9.0

Sources: NHSDA 1988, 1990 through 1993; STRIDE 1981 through 1993

Number of marijuana users

More Americans use marijuana than either cocaine or heroin. During 1993, for example, about 9 million Americans used marijuana or hashish at least once in the month before the survey. This number has decreased 23 percent since 1988, when it was almost 12 million.

Average number of joints used each month

We calculated an individual's total number of joints used each month by multiplying the number of days of marijuana use in the past month by the number of joints used per occasion. For those without valid answers for these questions, we imputed the total monthly use (see Appendix 4). The average number of marijuana joints used in the past month has remained about the same (16.9 to 17.8 joints).

Average amount of marijuana used

The average amount of marijuana used in the past month was calculated from several questions in the survey (see Appendix 4). This number has changed little over time — about 0.014 ounces per joint.

However, the average number and weight of joints used by those who smoke marijuana cannot tell the entire story about trends in marijuana use, because marijuana's THC content has changed over time. Delta-9 tetrahydrocannabinol (THC) is marijuana's primary psychoactive chemical. According to

a study conducted at the University of Mississippi[29] the average THC content of sinsemilla was at a peak in 1990 and 1991. That average fell from 10.5 percent in 1991 to 8.6 percent in 1992, and to 6.0 percent in 1993. The THC content of commercial-grade marijuana remained fairly constant at less that 4.0 percent from 1985 to 1992, but jumped to about 5.4 percent in 1993. Because we do not know the mix of sinsemilla and commercial-grade marijuana used by the typical user, we cannot know, for certain, whether users are smoking more or less marijuana as measured by THC content.

Price

Price is the final factor in calculating the total value of marijuana consumption. (See Appendix 4.) Marijuana prices increased throughout most of this period, but fell in 1993.[30] These prices are for a one-third ounce purchase.

Total consumption estimates

The factors required to calculate total marijuana consumption are shown in Table 6. In 1993, average users consumed 17.8 joints a month. The average amount of marijuana used per joint equaled 0.0136 ounces. At a retail price of $342 an ounce, these users spent an average of $83 each month ($998 a year) on marijuana. This number, multiplied by the 9.0 million monthly users, yields a consumption estimate of $9.0 billion. These estimates of total spending are in line with estimates by others.[31]

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[29] National Narcotics Intelligence Consumers Committee, *The NNICC Report 1993: The Supply of Illicit Drugs to the United States*, (Washington, D.C., August 1994): 61.

[30] This recent decrease in marijuana prices is also described in the National Institute on Drug Abuse's Community Epidemiological Working Group (CEWG) bi-annual reports on drug abuse trends across the country. Community Epidemiology Work Group, *Epidemiologic Trends in Drug Abuse*, (Rockville, MD: National Institute on Drug Abuse, June 1994).

[31] Using several self-report surveys, BOTEC Analysis Corporation, in an ONDCP report, estimated that marijuana costs $222 an ounce and that an ounce could be divided into 60 joints, yielding a unit price of $3.70 per joint. Based on these assumptions, BOTEC estimated that Americans spent $13.1 billion on 1,599 tons of marijuana in 1992. BOTEC's estimate is greater than the estimate presented in this report. The difference can be accounted for by three factors: methodological differences in estimating the number of users in NHSDA; BOTEC's inclusion of criminally active user estimates; and BOTEC's higher price estimates. A.L. Chalsma and D. Boyum, "Marijuana Situation Assessment," (Washington, D.C.: Office of National Drug Control Policy, September 1994).

Nevertheless, these estimates are probably low. Users are likely to underreport socially disapproved behaviors even when those behaviors are legal.[32] They would seem to have even more incentive to underreport illegal behaviors.[33] Some readers might find it reasonable to inflate these estimates for marijuana consumption by about one-third.[34]

OTHER DRUGS

Most of the money spent on illicit drugs in America is spent on cocaine, heroin, and marijuana. However, the expenditures on other illicit substances (inhalants and hallucinogens) and on licit substances consumed illegally (stimulants, sedatives, tranquilizers, and analgesics) is not small. Much of this drug use appears to be reported to the NHSDA.[35] We do note, however, that the NHSDA undoubtedly misses some users, and those who are reached probably have an incentive to misrepresent their consumption.

Table 7 shows the number of respondents who, according to the NHSDA, used these other drugs between 1988 and 1993. Those respondents who admitted use during the year were asked how frequently they used the drug.[36] We then used these data to compute an average number of days a year that the respondents used a drug.[37] Since the survey does not have information about the number of doses taken on days that the drug was used, we assumed that each day of use resulted in a single dose. This is most certainly an underestimate.

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[32] Researchers disagree about trends in reporting practices, but they agree that self-reported tobacco use is only about three-quarters as large as reports based on foreign imports and tobacco sales resulting in state and federal excise taxes. K.E. Warner, "Possible Increases in the Underreporting of Cigarette Consumption," *Journal of the American Statistical Association*, 73 (1978):314-317. E.J. Hatziadreu, J.P. Pierce, M.C. Fiore, et. al., "The Reliability of Self-Reported Cigarette Consumption in the United States," *American Journal of Public Health*, 79, (1989): 1020-1023.

[33] In 1993, about 74 percent of arrestees who tested positive for marijuana use at the time of booking reported some marijuana use during the month before the survey.

[34] The two previous notes indicate that respondents will report about three-quarters of the marijuana that they use. An earlier estimation methodology added estimates based on arrestee urine testing to estimates based on the NHSDA and subtracted the overlap. However, evidence indicates that this overlap is substantial, because most arrestees who test positive for marijuana (we estimate this as about 2.0 million) also appear in the NHSDA (we estimate this as 1.3 to 1.9 million based on self-reports of being arrested). The overlap would be even greater if NHSDA respondents underreport past arrests. Hence, we abandoned the earlier methodology, which appeared in W. Rhodes and D. McDonald, "What American's Users Spend on Illegal Drugs," (Technical paper for the Office of National Drug Control Policy, (June 1991).

[35] We noted previously that heavy cocaine users and heavy heroin users frequently appear in the DUF data, but infrequently appear in the NHSDA data. The reverse occurs for other illicit substances. With few exceptions, which are specific to cities, other illicit substances have relatively low prevalence among arrestees.

[36] Their answers, which were in ranges of days per year, were converted to a fixed number. For instance, the range three to five days became four days.

[37] Estimates of frequency of use from the 1991 NHSDA were applied to earlier years.

It is difficult to determine prices per dose. Both the Drug Enforcement Administrations's (DEA) Illegal Drug Price/Purity Report and the National Institute on Drug Abuse's Community Epidemiological Working Group (CEWG) provided wide ranges.[38] For current purposes, we assumed that each dose costs $5, a price that was consistent with those reported by the DEA and the CEWG. These street prices may be too high, however, because many of the legal drugs were likely to have been purchased at prescription prices and diverted to illegal use.

To estimate the yearly expenditures on these drugs, we multiplied three factors: the number of users, by the average number of doses per year, by the price per dose. Our best estimate is that Americans spent between $2 billion and $3 billion on other drugs during each of the last six years (Table 7).

TABLE 7

Other Drugs: Total Yearly Users (thousands) and Expenditures ($ in billions, 1994 dollar equivalents), 1988-1993

Drug Used	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*
Number of Users						
Inhalants	2,631	2,508	2,385	2,565	2,036	2,092
Hallucinogens	3,085	2,676	2,266	2,470	2,440	2,391
Stimulants	4,953	4,031	3,108	2,694	1,981	2,377
Sedatives	3,096	2,665	2,233	2,130	1,806	1,582
Tranquilizers	4,403	3,471	2,538	3,358	3,046	2,543
Analgesics	5,308	5,154	4,999	5,076	4,884	4,571
Expenditures	**$3.2**	**$2.8**	**$2.3**	**$2.4**	**$2.2**	**$1.8**

Source: NHSDA 1988, 1990 through 1993

These estimates are imprecise for the reasons noted above. However, even if we halve or double the estimates to reflect uncertainty, drugs other than cocaine, heroin, and marijuana must be a relatively small part of the total expenditure that Americans make on illicit substances and on legal substances consumed illegally.

[38] Drug Enforcement Administration, *Illegal Drug Price/Purity Report United States: January 1990—December 1993*, April 1994. Community Epidemiology Work Group, *Epidemiologic Trends in Drug Abuse*, (Rockville, MD: National Institute on Drug Abuse, June 1994).

CONCLUSION

According to the consumption-based procedure, Americans spent almost $49 billion on heroin, cocaine, marijuana, and other illegal drugs in 1993: $31 billion on cocaine, $7 billion on heroin, $9 billion on marijuana, and $2 billion on other illegal drugs (Table 8). During the period from 1988 to 1993, the number of people who used marijuana fell, but total expenditure on marijuana remained almost constant, because prices increased until 1993, when they began to decline. Cocaine expenditures fell for several reasons: there were fewer occasional users, an increasing number of hardcore users were in jail or prison, and cocaine prices fell. Expenditures on heroin also fell. The AIDS epidemic is one likely explanation, but we also note that the price of heroin declined as its purity increased. Expenditures on other illicit drugs appeared to fall over time.

In this section of the report we examined the use of drugs, that is, the demand for illicit drugs and for licit drugs used illegally. In the next section, we examine the availability of illegal drugs in the domestic market.

TABLE 8

Total Expenditure on Illicit Drugs, 1988-1993
($ in billions, 1994 dollar equivalents)

	1988	*1989*	*1990*	*1991*	*1992*	*1993*
Cocaine	$41.1	$42.5	$38.9	$35.2	$33.1	$30.8
Heroin	$11.2	$11.5	$10.3	$8.2	$7.0	$7.1
Marijuana	$8.9	$9.0	$9.6	$9.0	$10.1	$9.0
Other Drugs	$3.2	$2.8	$2.3	$2.4	$2.2	$1.8
Total	**$64.4**	**$65.7**	**$61.1**	**$54.8**	**$52.4**	**$48.7**

Note: Columns may not add due to rounding error.
Source: Tables 1 through 7.

II. THE SUPPLY APPROACH

A second approach to estimating the amount that Americans spend on illicit drugs is to estimate the value of shipments *supplied* to domestic markets. This section discusses the information and assumptions we used to estimate the supply of cocaine to the United States. For reasons discussed below, it is not practical to develop estimates for heroin, marijuana, and other illegal drugs.

COCAINE

This section focuses on the production and distribution of cocaine. Although the production and distribution data we use are the best available, we doubt that they totally reflect the real processes by which coca leaves are converted into cocaine and distributed. Further, both the cocaine production and distribution processes are subject to numerous losses such as spoilage, seizures,[39] and consumption[40] in countries other than America. Rather than making highly speculative estimates of the amount of losses, we only estimate losses resulting from federal seizures, which are reported reliably, and source country seizures, which are more speculative.[41] As a result, our estimates of the amount of cocaine supplied to domestic markets are considerably higher than if we took into account the losses noted above.

Cocaine production

The production and distribution of cocaine starts in South America, principally in the Andean nations, with the cultivation of coca plants by farmers, and ends with retail-level drug dealers in the United States. Figure 1 depicts the production and distribution flow. Coca leaves are harvested and then chemically treated to produce coca paste. The paste is treated further to create "base." Another chemical process turns the base into cocaine hydrochloride (HCl), or pure cocaine. The cocaine is then shipped directly to consumer countries or is transshipped through other countries.[42]

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[39] Information about seizures is of questionable reliability. Besides providing an incentive for both over- and undercounting at various junctures, mislabeling of seizures can result in errors of calculation. Some estimates are quite speculative.

[40] Data are inadequate to derive estimates of drug use practices in Central and South American nations, but limited data indicate that consumption must be significant. For example, the Mexican government sampled 15,000 households in urban areas, interviewing individuals who were 12 to 65 years old. Roughly 0.5 percent of males (12-34 years old) in the northern part of the country used heroin in the year before the survey; cocaine was used by 3.4 percent in the northwest, 1.0 percent in the northeast, and 1.2 percent in the central north. M. Medina-Mova, "Drug Abuse in Northern Mexico: Results from a National Household Survey," in *Epidemiologic Trends in Drug Abuse, Proceedings June 1990* (NIDA, 1990). Although estimates are elusive, internal consumption of coca leaves and its derivative is high in producing countries. For example, an estimated 1 million Peruvians across 20 cities chewed coca leaf, 200,000 smoked coca paste, and over 100,000 inhaled cocaine hydrochloride. F. Jeri, "Some Recent Facts about Drug Abuse in Peru," in *Epidemiologic Trends in Drug Abuse, Proceedings June 1990* (NIDA, 1990). Indeed, until recently, Bolivian and Peruvian law permitted limited domestic production of coca for domestic consumption - 12,000 kilograms in Bolivian and 14,000 kilograms in Peru, according to J. Inciardi, *The War on Drugs II* (Mayfield Publishing: California, 1992). In addition to consumption within producer countries, spoilage and in-kind payments for shipping must be a major loss to the cocaine industry.

[41] Losses include shipments that were left for a trafficker, but never picked up. Losses also occur when a trafficker abandons his cargo at sea when he is pursued by authorities.

[42] For a detailed discussion of cocaine processing, see Drug Enforcement Agency, Office of Intelligence, *Coca Cultivation and Processing: An Overview* (Washington, D.C.: U.S. Department of Justice, February 1991). The cocaine production process varies from one processor to another and there is a new method being used to process cocaine in some regions. This process, called *agua rica*, can be used to skip one of the intermediary steps. The process is used for a variety of reasons, but is not known to increase the cocaine yield from the coca leaf.

FIGURE 1

COCAINE PRODUCTION AND DISTRIBUTION PROCESS

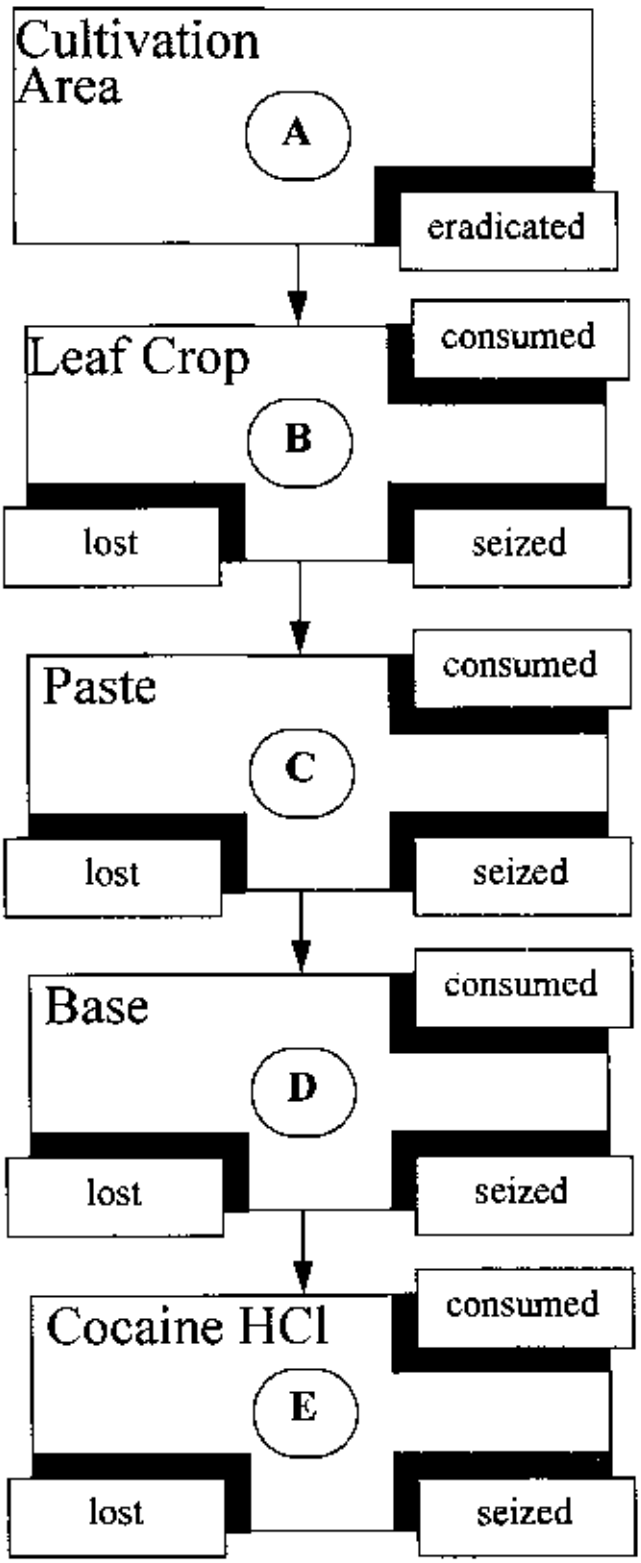
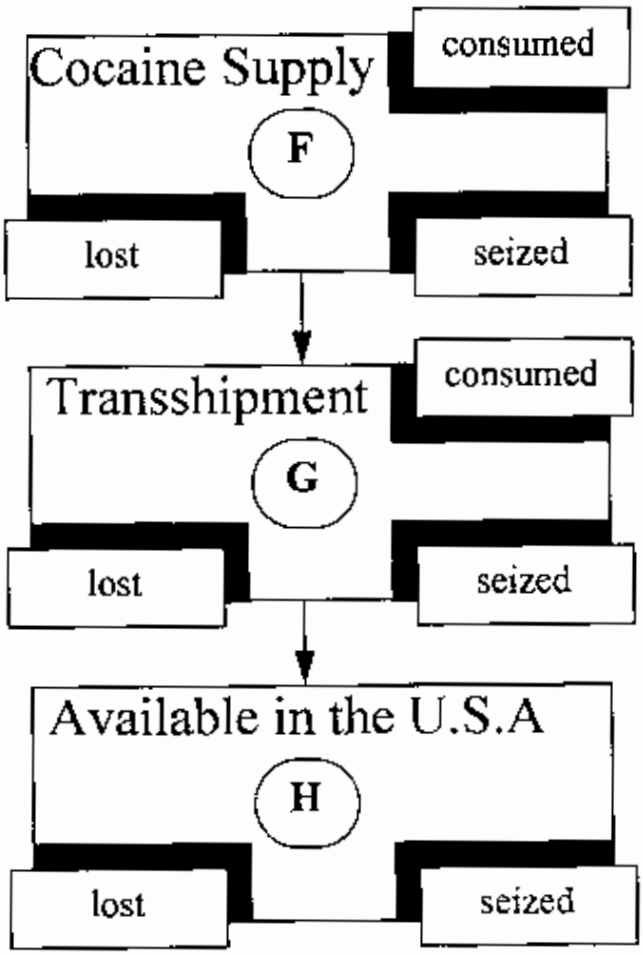


FIGURE 1 - CONTINUED

COCAINE PRODUCTION AND DISTRIBUTION PROCESS



We developed a computer model for each of the stages in this process (Figure 2) from cultivation through transportation of the product to consumer markets.[43] The letter next to each box in Figure 2 corresponds to the letters in Figure 1.

Coca cultivation (Box A). Estimates of the amount of land under cultivation in the major coca producing countries (Peru, Bolivia, Colombia and Ecuador[44]) are published annually by the Department of State in the *International Narcotics Control Strategy Report (INCSR)*.[45] According to the *INCSR*, about 186,959-210,826 hectares[46] were under cultivation for coca leaf during 1993. If we take the midpoints of these ranges, this is less than the amount reported in 1992 (204,788-230,931 hectares) and 1991 (195,755-229,800 hectares).

Eradication efforts by the governments in producer countries, sometimes with the assistance of the United States, reduce harvestable coca leaves. In 1993, 3,193 hectares (1.6 percent of the total area reported under cultivation) were eradicated,[47] leaving about 183,766-207,633 hectares under cultivation.

Coca plant yields (Box B). The State Department calculates coca leaf yields using the assumption that bushes can be harvested three or four times a year. We use these assumptions in our model.[48] In 1993, there was a dramatic decline in the harvest of

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[43] The computer model is an adaptation of a preliminary version of a cocaine supply model developed by RAND Corporation. Our model uses various kinds of information. These include estimates of (1) land area under cultivation in known producer countries, (2) eradicated cultivation areas, (3) coca leaf crop yield , (4) the efficiency of the process for converting leaf to intermediary products and then to cocaine, and (5) losses, consumption, and seizures within producer countries.

[44] Coca is reportedly cultivated in Brazil and Venezuela, but estimates of hectares under cultivation are not available.

[45] Bureau of International Narcotics Matters, *International Narcotics Control Strategy Report* (Washington, D.C.: Department of State Publications, April 1994, and previous years). The Bureau bases its calculations of land under cultivation on "proven methods similar to those used to estimate the size of licit crops at home and abroad."

[46] One hectare equals 2.47 acres.

[47] *INCSR, 1994.* We assume for the purposes of the model that eradication is in the primary coca growing regions.

[48] The conversion process can vary widely from one location to another in the processing countries. According to information now available from a variety of sources, the *INCSR* accurately reflects the conversion process in each of the producer countries. J. Inciardi, *The War on Drugs* (Palo Alto, CA: Mayfield Publishing Company, 1986), 71-89; and telephone interviews with E. Morales, West Chester University, PA.

FIGURE 2

WORLDWIDE COCAINE FLOW, 1993

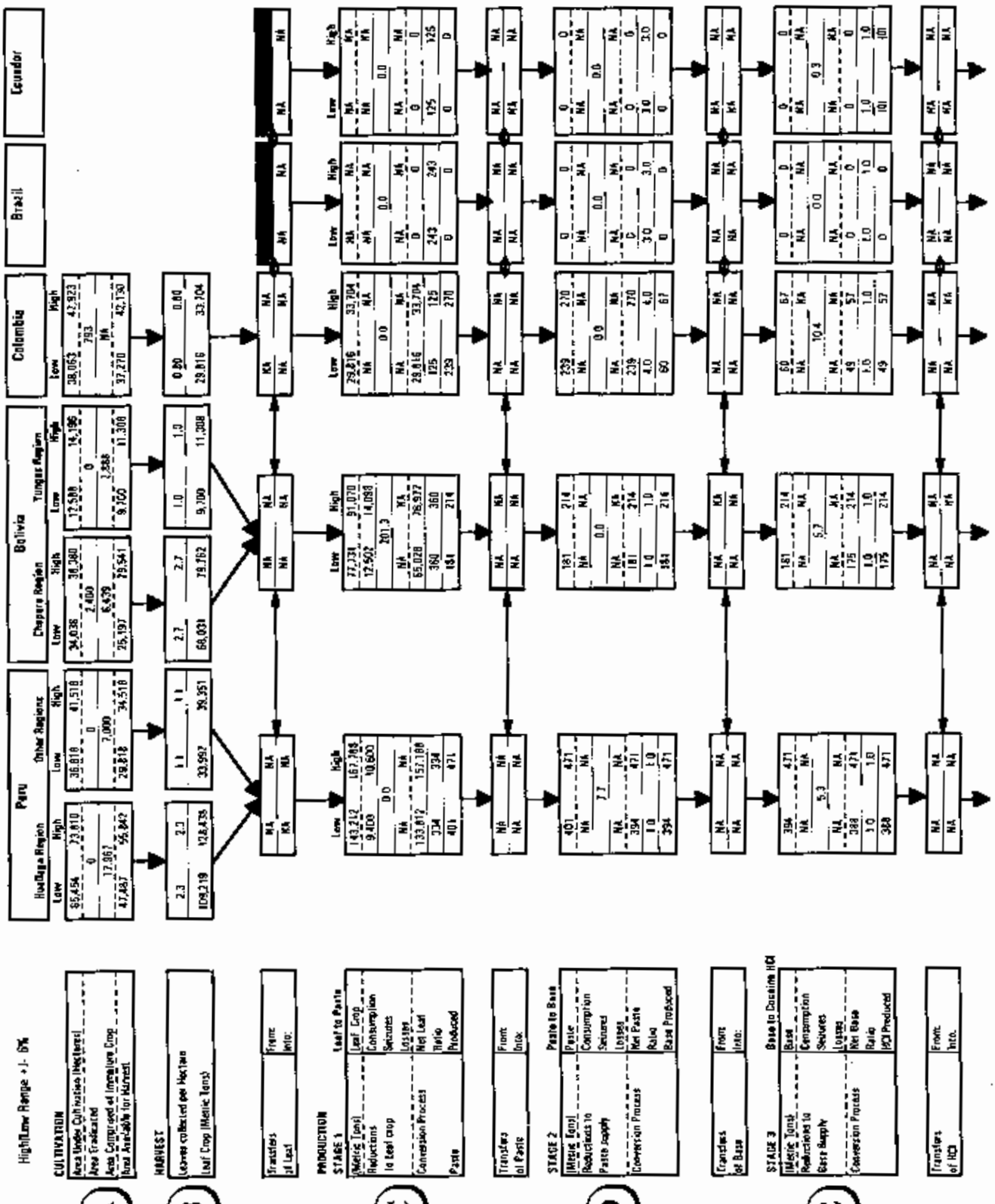


FIGURE 2 - CONTINUED
WORLDWIDE COCAINE FLOW, 1993

Cocai- HCl

(Metric tons)	HCl
Reductions to HCl	Consumption
	Seizures
	Losses
Available HCl	for Export

388	471	175	214	49	57	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0.5		0.3		21.8		7.7		1.0	
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
388	471	175	213	27	35	(8)	(8)	(1)	(1)

Available for Export	
Low	High
581	711

F

TRANSSHIPMENT

Bound for the United States	75%
Bound for Other Countries	25%

G

UNITED STATES BOUND SHIPMENTS

Percent of Total: 75%

AMOUNT	Low		High
	436		533
Venezuela			
Consumption	NA		NA
Seizures		1.500	
Losses		NA	
Chile			
Consumption	NA		NA
Seizures		0.000	
Losses		NA	
Panama			
Consumption	NA		NA
Seizures		5.700	
Losses		NA	
Costa Rica			
Consumption	NA		NA
Seizures		0.611	
Losses		NA	
Nicaragua			
Consumption	NA		NA
Seizures		0.558	
Losses		NA	
Honduras			
Consumption	NA		NA
Seizures		2.640	
Losses		NA	
El Salvador			
Consumption	NA		NA
Seizures		8.163	
Losses		NA	
Guatemala			
Consumption	NA		NA
Seizures		7.603	
Losses		NA	
Belize			
Consumption	NA		NA
Seizures		0.010	
Losses		NA	
Mexico			
Consumption	NA		NA
Seizures		46.200	
Losses		NA	
The Caribbean			
Consumption	NA		NA
Seizures		6.724	
Losses		NA	
Canada			
Consumption	NA		NA
Seizures		2.731	
Losses		NA	

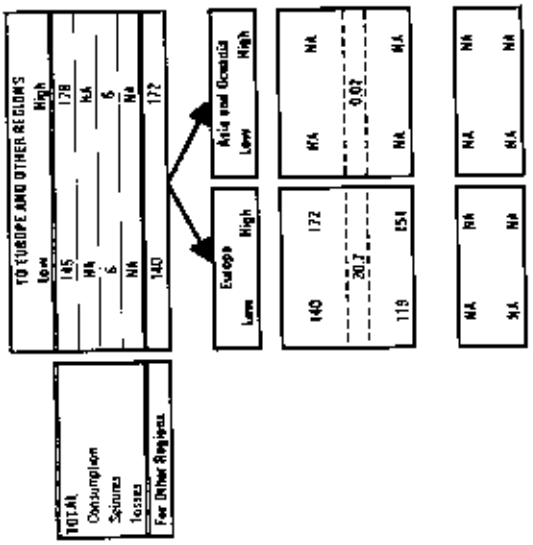
TO EUROPE AND OTHER REGIONS

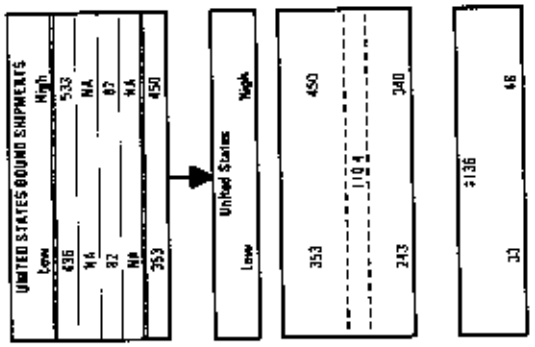
Percent of Total: 25%

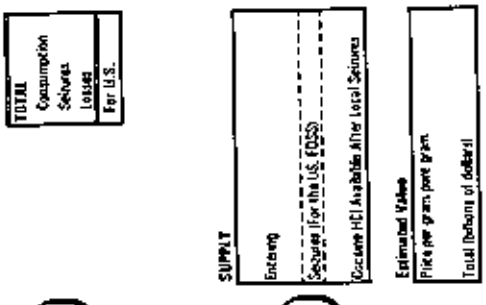
AMOUNT	Low		High
	145		178
Venezuela			
Consumption	NA		NA
Seizures		0.500	
Losses		NA	
Guyana, Suri., Fr. Gui.			
Consumption	NA		NA
Seizures		0.463	
Losses		NA	
Paraguay			
Consumption	NA		NA
Seizures		0.047	
Losses		NA	
Uruguay			
Consumption	NA		NA
Seizures		0.000	
Losses		NA	
Chile			
Consumption	NA		NA
Seizures		0.000	
Losses		NA	
Argentina			
Consumption	NA		NA
Seizures		1.100	
Losses		NA	
The Caribbean			
Consumption	NA		NA
Seizures		2.241	
Losses		NA	
Nigeria			
Consumption	NA		NA
Seizures		0.047	
Losses		NA	
Middle East			
Consumption	NA		NA
Seizures		0.021	
Losses		NA	
Africa Other			
Consumption	NA		NA
Seizures		0.018	
Losses		NA	
Russia			
Consumption	NA		NA
Seizures		1.092	
Losses		NA	

FIGURE 2 - CONTINUED

WORLDWIDE COCAINE FLOW, 1993







coca leaves due to a fungus that attacked coca plants in Peru. In 1993, a total of 250,759-292,561 metric tons of leaves were harvested. This is less than the amount reported in 1992 (309,840-356,211 metric tons) and 1991 (304,182-357,218 metric tons).

Coca manufacturing (Boxes C through E). Converting the coca leaves into cocaine HCl requires laboratory equipment and large quantities of chemicals. Information about processing and the network of clandestine laboratories[49] is based on in-depth research on the production process that has been undertaken by the Drug Enforcement Administration.

Leaf to Paste Conversion (Box C). Two factors affect the amount of paste produced from treating coca leaves. First, the leaves grown in different countries have different alkaloid content.[50] Because the conversion ratio varies with the leaves' alkaloid content, the conversion ratio varies from country to country. Second, the indigenous population in Bolivia and Peru consume coca leaves. Figure 2 shows modest consumption levels for both Peru and Bolivia.

Paste to Base Conversion (Box D). This stage, which may not be followed in all regions, is a relatively simple "washing" of the coca paste in acetone before the final purification process. This increases the purity of the final product.

Base to Cocaine HCl (Box E). This stage requires acetone, ether, and hydrochloric acid that are produced in many industrialized nations. One unit of base yields an equal unit of cocaine HCl.

As shown in Table 9, this cultivation and manufacturing process resulted in an estimated 581 to 711 metric tons of pure cocaine that were available for shipment to world markets in 1993.[51] As described below, however, not all of this cocaine is shipped to the principal consumer countries.

Cocaine transshipment (Box G)

Cocaine is shipped from manufacturing countries (such as Colombia) to the primary consumer countries (principally the United States) by many modes and usually through a third country. Some cocaine is shipped directly to the consumer countries. To avoid detection, however, most of it is transshipped through other countries such as the Caribbean nations, South and Central Americancountries, Canada, and Mexico.[52] Some cocaine losses occur during these shipments.

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[49] Clandestine laboratories are located in the cultivating countries and in Argentina, Brazil, and Venezuela.

[50] For example, Colombian coca leaf has about half the alkaloid content of leaf from Peru or Bolivia. *INCSR, 1992.*

[51] The range reflects different assumptions about consumption of coca leaf in Bolivia and Peru.

[52] According to the United Nations, 70 percent of all cocaine destined for the United States is transshipped through Mexico. United Nations, International Narcotics Control Board (INCB), *Report of the International Control Board for 1991* (Vienna, 1990).

TABLE 9

Estimates of Cocaine HCl Available in the United States in 1993
(in metric tons)

	Low	High
Cocaine HCl Available for Export	581	711
From Producing Countries[1]	436	533
Foreign Seizures of Cocaine destined for the United States[2]	-82	-82
Cocaine shipped to the United States	353	450
Federal Seizures[3]	-110	-110
Cocaine Available for consumption in the United States	243	340

[1] Estimates of Cocaine HCl come from the computer model of cocaine production. The range is based on the error band reported by the Department of State for the area under cultivation.

[2] *INCSR*, April 1994 and Royal Canadian Mounted Police, *National Drug Intelligence Estimate, 1994*.

[3] Drug Enforcement Administration, Federal-wide Drug Seizure System.

Note: Some numbers may not add up due to rounding.

Some of the cocaine is consumed in the transshipment countries, but it is difficult to determine how much for a number of reasons. For example, drug use surveys from these countries are usually limited in scope, and the methodology changes from year to year. Accordingly, we have made no adjustments in our model for these losses.

The amount of cocaine available in consumer countries is further reduced by foreign seizures. According to the *INCSR*, authorities in producer, transshipment, and other consumer countries seized about 82 metric tons of cocaine in 1993 that was destined for the United States market (Table 9).[53]

Of the remaining amount, about 25 percent is diverted to consumer countries other than the United States. (This estimate lacks firm grounding, but is probably reasonable enough to capture the actual proportion consumed outside the United States.) Based on these assumptions, we estimate that about 353 to 450 metric tons of cocaine were shipped to the United States in 1993 (Table 9).

The U.S. cocaine market (Box H)

Of the amount of cocaine shipped to the United States, Federal authorities seized about 110 metric tons, leaving 243 to 340 metric tons of pure cocaine for domestic consumption during 1993 (Table 9). This is a decrease from the 1992 estimates of 376 to 539 metric tons (due to the fungus that affected the harvest in Peru).

Using the midpoints of the estimates of price per pure gram from Table 4, the total retail value of 246 to 343 metric tons is between $33 and $46 billion in 1993.[54] (This compares with ranges of $55 to $79 billion in 1992 and $51 to $72 billion in 1991.) Again, we consider this estimate to be high because we could not fully account for the many reductions in the supply noted above.

Moreover, the $33 billion to $46 billion range is necessarily wide. As emphasized throughout this section, the data upon which these estimates are based are not sufficiently precise to support a narrower range of estimates. Given our knowledge of cocaine use and price, it is unlikely that the retail sales expenditure on cocaine approaches $46 billion dollars.[55] When drug expenditures as income in kind are considered, however, the lower end of this range is consistent with estimates based on our analysis of drug consumption (Table 8).

Based on the midpoints of the ranges reported in Table 10, leaf crops increased slightly from 1989/1990 to 1991/1992, and then fell sharply in 1993. This decrease was due to a fungus that attacked the coca plants in Peru. Combined Federal and foreign seizures have remained at about 200 metric tons. Consequently, the effect of the crop reduction in Peru may have resulted in a 30 percent reduction in cocaine supply from 1992 to 1993. It is doubtful that American markets were affected strongly (prices

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[53] *INCSR 1994* and United Nations, INCB, *Narcotic Drugs: Estimated World Requirements for 1993, Statistics for 1991*.

[54] Not all of the available supply of cocaine imported to the United States may be consumed in a given year: it may go into inventory or stockpiles in an effort to maintain or increase prices.

[55] A figure of $200 billion was reported by the Latin American Weekly report, with little substantiation. A similar figure has been cited by Webster and McCampell, attributed to Holmes, but the source of this estimate is obscure. *Latin American Weekly Report* (WR-91-12, March 28, 1991); B. Webster and M. McCampell, *International Money Laundering: Research and Investigation Join Forces* (NIJ Research in Brief, September 1992); C. Holmes, *Combating Money Laundering: An Arizona-Based Approach* (Police Executive Research Forum, March 1991). Such estimates seem impossibly large. If all $200 billion was attributable to cocaine, and if 2.2 million heavy cocaine users consume 80 percent of the available cocaine, then each user must be required to spend $72,000 per year on cocaine. In contrast, a heroin addict has been estimated to spend $257 per week on his or her habit - less than $14,000 per year. Even if only $100 billion is attributable to the cocaine market, a heavy user of cocaine would spend almost $874 on cocaine per week far more than is reported by hardcore users. Thus, $200 billion is certainly an excessively high estimate.

did not increase between 1992 and 1993), partly because of delays between growing coca leaves and delivering cocaine and crack on American streets, and partly because cocaine suppliers are known to stockpile supplies in anticipation of shortages.

TABLE 10

Trends in the Cocaine Supply, 1989-1993
(in metric tons unless otherwise noted)

	1989	*1990*	*1991*	*1992*	*1993*
Cocaine HCl available for export from producing countries[1]	708-857	705-858	748-941	771-989	581-711
Cocaine destined for the United States	531-643	529-643	561-705	578-742	436-533
Foreign seizures of cocaine destined for the United States[2]	55	85	96	83	82
Cocaine shipped to the United States	476-588	444-559	465-609	495-659	353-450
Federal Seizures[3]	115	96	128	120	110
Cocaine available for consumption in the United States	361-473	348-463	337-481	376-539	243-340
Retail value of cocaine in the United States (in billions of dollars)	$52-68	$67-90	$51-72	$55-79	$33-46

[1] Estimates of cocaine HCl come from the computer model of cocaine production. The range is based on the error band reported by the Department of State for the area under cultivation.

[2] *INCSR*, April 1994 (and previous years); Royal Canadian Mounted Police, *National Drug Intelligence Estimate, 1994* (and previous years) and International Narcotics Control Board, Narcotic Drugs Statistic for 1991 (and previous years).

[3] Drug Enforcement Administration, Federal-wide Drug Seizure System, 1989-1993.

HEROIN

Poppy plants, from which opium is extracted, are grown in Southeast Asia, Southwest Asia, and in the Western Hemisphere (Mexico, Guatemala, and Columbia). Opium is converted into heroin in laboratories in the countries where it is cultivated and in other countries, and then consumed locally or shipped to consumer countries.

There are two reasons why we cannot develop a supply flow model for Southwest and Southeast Asia heroin. First, it is difficult to estimate the total harvest in these areas. For example, estimates of areas under cultivation in Iran have been unavailable since the Islamic Republic broke off ties with the United States. The second problem is that Europe and North Africa are the primary export markets for heroin from these regions. This makes it difficult to determine the amount of heroin shipped to the United States.

In contrast, the United States is the only major market for Mexican, Guatemalan, and probably Colombian heroin.[56] Therefore, we can integrate the heroin production process in the Western Hemisphere into a computer model similar to the cocaine model. Using information from the 1994 *INCSR* on the amount of land under cultivation and opium yields, we estimated the amount of heroin available for export to the United States from these countries. We then used these estimates as the basis for determining the entire U.S. heroin market: Using DEA's Heroin Signature Program (HSP)[57], we calculated the U.S. share of the worldwide market based on the percentage of Western Hemisphere heroin in the market.[58]

We estimate that approximately 32 metric tons of heroin were available in the United States in 1993. We derived these figures by using the *INCSR's* estimate of 7.3 metric tons of heroin from the Western Hemisphere in 1993, and by assuming that 23 percent (based on the HSP) of the U.S. market comes from the Western Hemisphere. Discounting for the 1.4 metric tons Federal authorities seized in 1993, we estimate the total U.S. heroin market to be 31.6 metric tons in 1993. Using the midpoints of the estimates of price per pure gram from Table 4, we estimate the total retail value of this heroin to be approximately $54 billion.

These estimates are well above what we would reasonably expect. The largest credible estimate of the number of heroin addicts is about 1 million, and this estimate is considered to exceed the actual number.[59] We reasoned earlier that heroin addicts are unlikely to spend more than $420 a week, and few are likely to spend this much. We also reasoned that about 87 percent of expenditures on heroin could be attributed to addicts.[60] However, even if we make all of these extreme assumptions, heroin expenditures cannot exceed approximately $25 billion.[61] Therefore, we conclude that the supply-based model for heroin is not credible.

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[56] The Royal Canadian Mounted Police report that Mexican and Central American heroin in Canada is under five percent. RCMP, *National Drug Intelligence Estimate 1994*. According to data on origins of seizures in Europe, no couriers originated in Mexico (International Criminal Police Organization. *The Heroin Situation in Europe in 1989* (Lyons, France, February 1990).

[57] The Heroin Signature Program (HSP), using a random sample from all seizures and purchases registered in STRIDE, tries to quantify the U.S. market shares of each of the three major heroin producing areas. The HSP analyzes 300 to 500 exhibits annually from a random sample of purchases and seizures made by Federal agents. This analysis probably does not reflect the U.S. heroin market as a whole. See *The NNICC Rport, 1993: The Supply of Illicit Drugss in the United States* (Washington, D.C.: National Narcotics Intelligence Consumers Committee, August 1994).

[58] For example, suppose X is the amount of heroin from Western Hemisphere sources, and suppose that Y percent of the U.S. market is met by those Western Hemisphere sources. Then, the worldwide supply of heroin sent to the United States must equal X/Y.

[59] D. Hamill and P. Cooley, *National Estimates of Heroin Prevalence 1980-1987: Results from Analysis of DAWN Emergency Room Data* (RTI Report, Triangle Park, N.C.: Research Triangle Institute, 1990).

[60] This percentage would certainly be larger if we assumed that 1 million addicts spent $420 per week on heroin.

[61] Multiply 1 million addicts by $420 per week by 52 weeks and divide by 0.87.

MARIJUANA

It is difficult to develop an estimate of the size of the U.S. retail market for marijuana from estimates of available supply. First, the amount of marijuana that Americans cultivate for personal use is impossible to estimate. Second, even though a large amount of the domestic marijuana market is grown in the United States,[62] countries in South and Central America, the Caribbean, Asia, North Africa, and the Middle East also supply cannabis to the domestic market. Unfortunately, the data needed to develop better estimates are not available, and without the independent ability to assess the reliability of the marijuana cultivation estimates, we cannot develop a plausible supply-based estimate of the retail value of the marijuana market in the United States.

LEGITIMATELY MANUFACTURED CONTROLLED SUBSTANCES AND ILLICITLY MANUFACTURED DANGEROUS DRUGS

It is impossible to know the amount of controlled substances, such as inhalants and hallucinogens, that are diverted for illicit consumption. It is also impossible to know the amount of illicitly manufactured dangerous drugs. We do know that these substances are readily available.[63]

PRICE AND PURITY OF ILLICIT DRUGS

In lieu of solid estimates of the amount of cocaine, heroin, marijuana, and other illicit drugs, prices and purity offer some information about the availability of drugs in the United States. Because this report focuses on the amount spent on illicit drugs and the amount available, we will not discuss in detail the prices and purity.[64] As can be seen in Table 4, prices of cocaine have remained relatively stable over the past six years (except for 1990) and have declined for heroin (except for 1991). Marijuana prices (Table 6) have increased since 1988, but began to decline in 1993. Prices of other drugs were stable for this time period. Given that the number of hardcore users has remained fairly constant, stable or decreasing prices may indicate that these illicit substances are more readily available in the United States.

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[62] The DEA no longer estimates the amount of marijuana under cultivation outdoors in the United States. The DEA also notes that indoor cultivation continues and that there is no way to estimate the extent of this practice. *The NNICC Report, 1993: The Supply of Illicit Drugs to the United States* (Washington, D.C.: National Narcotics Intelligence Consumers Committee, August 1994).

[63] Drug Enforcement Administration, Intelligence Division, *U.S. Drug Threat Assessment* (Washington, D.C.: U.S. Department of Justice, 1993).

[64] There are many sources for drug price information. The Drug Enforcement Administration produces the *Illegal Drug Price/Purity Report* regularly. Abt Associates Inc. calculates average prices for the Office of National Drug Control Policy on a quarterly basis. Also see: J. Caulkins, *Developing Price Series for Cocaine* (Santa Monica, California: RAND, Drug Policy Research Center, 1994); W. Rhodes, R. Hyatt, and P. Scheiman, "The Price of Cocaine, Heroin and Marijuana, 1981-1993," *The Journal of Drug Issues*, 24, no.3 (1994): 383-402.

III. SUMMARY

Because of the quality of available data, there is considerable imprecision in estimates of the number of hardcore and occasional users of drugs, the amount of drugs they consume, and the retail sales value of those drugs. The best estimates (all for 1993) follow:

- In 1993, about 2.1 million Americans were hardcore cocaine users, and about 500,000 were hardcore heroin users. The number of hardcore cocaine users has remained fairly stable over the last six years (2.5 million in 1988). The number of hardcore heroin users has declined slightly, from 590,000 in 1988.

- About 4.0 million Americans were occasional cocaine users, and about 230,000 were occasional heroin users. Both numbers have decreased over the last six years. The number of occasional cocaine users dropped from 7.3 million in 1988, and the number of occasional heroin users decreased from 540,000 in 1988.

- More Americans use marijuana than either cocaine or heroin. In 1993, about 9.0 million Americans had used marijuana at least once in the month prior to being surveyed. The number of marijuana users has fallen since 1988, when 11.6 million Americans admitted using marijuana.

- Many Americans use illicit drugs other than cocaine, heroin, and marijuana, or they may use licit drugs illegally. About 16 million Americans admitted using these other drugs in 1993. This number has declined from 23 million in 1988, with the greatest decreases in the number of Americans who use stimulants, sedatives, and tranquilizers. These numbers include some overlap of polydrug users.

Deriving estimates of the total expenditure on illicit drugs and licit drugs consumed illegally is more difficult and uncertain because those estimates require more data about prices paid. Nevertheless, the best estimates indicate the following:

- Americans spent about $31 billion on cocaine, $7 billion on heroin, $9 billion on marijuana, and $2 billion on other substances. Income in kind earned by drug dealers and others probably adds about $2 to $3 billion to the cocaine figure and another $3 billion for heroin.

- Again, estimating trends is risky, but it appears that expenditures on cocaine, heroin, and other drugs have fallen some over the last six years. In contrast, expenditures on marijuana have remained constant.

Estimates of the total amount of cocaine consumed are lower than, but broadly consistent with, estimates of the total amount of cocaine available for consumption in 1993:

- From the supply-side perspective, 243 to 340 metric tons of cocaine were available for consumption in the United States.

- From the consumption perspective, Americans consumed roughly 215 to 382 metric tons of cocaine.

Although the estimates from the supply-side perspective are higher than those from the consumption perspective, the supply-side estimates are surely overstated. First, they do not exclude some losses that occur within the source countries but that cannot be readily estimated; and second, they do not account for domestic seizures by State and local officials. Although the supply-side and the consumption estimates are remarkably close, they cannot be completely reconciled.

The sizable price increase seen during 1990 is not reflected in a comparable decrease in the supply of cocaine available during 1990. This may have occurred because the supply of cocaine on the street lags behind the supply of cocaine entering the country, which lags behind the harvest of coca leaves, so the supply-based and consumption-based estimates should not be in lock step. Still, how the supply of cocaine could have remained relatively constant across time while the price of cocaine increased (and apparently the consumption of cocaine decreased) during 1990 is a perplexing question.

Although these estimates paint a picture of drug consumption with an extremely broad brush, and although not all estimates can be reconciled, the approach we use provides an important perspective on what is *not known* about drug production and consumption and what *needs to be known* to better understand the policy choices available to the Nation.

We make no pretense here that the model and estimates we present in this report are fully adequate to the larger task of informing public policy decisions. They are, at best, a start, but they offer important possibilities of integrating what are otherwise often seen as disparate pieces of information about the consumption and supply of drugs.

We expect incremental improvements to the estimates and methods offered here, particularly as better data become available. We also expect improvement in the model, which will include systematic and analytic links between government policy and drug use. Thus, it is probably best to consider this an interim report. The estimates we present might be seen as an improvement over those reported in 1991 and as a prelude to improved estimates for 1994.

Moreover, the estimates by themselves have only modest importance - they tell us nothing more than that the drug trade is large, a conclusion that requires no special study. The real utility of these numbers is the development of a systematic methodology for integrating the various indicators - crops in foreign countries, drugs seized at the borders, arrests made in American cities, etc. - that can help policymakers to better understand the dynamics of the drug trade and to better fashion appropriate policy responses.

APPENDIX 1

ESTIMATING HARDCORE HEROIN USERS

The main text reports estimates of the number of Americans who were hardcore users of cocaine and heroin between 1988 and 1993. The methodology upon which those estimates rest involves several untested assumptions. Confidence in the estimation procedure would be strengthened if an entirely different approach that used different data led to similar estimates.

This appendix uses an alternate approach with different data to estimate the number of hardcore heroin users in 1989 and 1990. These alternate estimates are, in fact, close to those reported in the main text.

The Problem

The problem is to estimate the number of hardcore heroin users (H). Let M be the number of users who enter substance abuse treatment during a given year. Let P be the probability that a hardcore heroin user enters treatment during that same year. Then because H *P=M, an estimate of the number of hardcore heroin users is:

$$\hat{H} = \frac{\hat{M}}{\hat{P}} \qquad [1]$$

where "^" denotes an estimate. This appendix explains how M and P are estimated and provides the resulting estimate of H.

Estimating P

Turning first to P, an estimate could be based on self-reports of substance abuse treatment by a random sample of hardcore users. Although no such random sample is available, a project sponsored by the National Institute on Drug Abuse provides data that, with suitable statistical analysis, leads to an estimate of P. That project is the National AIDS Demonstration Research Project (NADR).

The NADR project interviewed intravenous drug users (IDUs) who had not been in treatment during the thirty days before the interview. Most of those interviews were done in 1989 and 1990. (Other people were interviewed by the NADR project, but only IDUs not in treatment are relevant here.) The present analysis considers all IDUs to be hardcore users, because needle use indicates an established heroin user. It assumes they began careers as hardcore heroin users the first time they injected, because this is the best estimate of addiction that the data provide. Call the time from first injection to the time of the interview "T_j," where *j* denotes the *j*th member of a sample. The analysis assumes that the IDUs provided an accurate account of the number of times they received substance abuse treatment in the period T_j. Call this "N_j." Treatment excludes self-help therapy.[1] The problem is to develop a stochastic model of entering

[1] Treatment includes drug detoxification, residential, prison/jail treatment programs, methadone maintenance, and outpatient drug-free. Altogether, 99.5 percent of the sample reported 4 or fewer treatment episodes per year of hardcore heroin use. Those who reported more were treated as data errors and were excluded from the analysis site.

treatment based on N_j, T_j, and covariates, and on the way the sample was drawn. This model is used to predict P for a given period.[2]

Five covariates enter a statistical model. The data were partitioned by gender (MALE) and ethnicity (WHITE, BLACK). NJAIL is the fraction of time spent in jail or prison during the five years before the interview, a crude measure of time at liberty to enter substance abuse treatment. AGE is the user's age at the time of the interview. Justification for including these variables appears later.

The stochastic model is based on T, N, and these five covariates. After rejecting simpler models, the analysis settled on a "three population model." The model's name implies that hardcore heroin users can be classified into three *conceptual* groups. The term conceptual requires emphasis: It is for analytical convenience and does not necessarily have behavioral implications.

The first conceptual group comprises hardcore users who have a zero probability of ever entering substance abuse treatment. The second comprises hardcore users who have not entered treatment by T but who have a non-zero probability of entering treatment in the future. The third conceptual group comprises hardcore users who have entered treatment at least once. At any time, these three groups exhaust the hardcore user population.

The reason for thinking about three conceptual groups is that the stochastic process that describes the timing between starting hardcore drug use and entering treatment for the first time seems different from the process that explains subsequent episodes of treatment. Consequently, it is useful to distinguish those who have not yet entered treatment from those who have. The stochastic processes based on just these two groups do not explain patterns in the data as well as is desired, however. Some improvement can be made by postulating the existence of a third group, namely, those who have a zero probability of ever entering treatment. Thus, these three conceptual groups are useful because they help explain patterns in entering substance abuse treatment.

The Model: A Formal Specification

By assumption, then, a hardcore heroin user has a probability Q of belonging to the first group, those with a zero probability of entering treatment. Q is written:

$$Q = \frac{1}{1 + e^{\delta}} \qquad [2]$$

where the Greek letter δ is a parameter to be estimated. (All parameters are represented by Greek letters here.) Given that δ is the same across all hardcore users, nothing important depends on the structural form of Q. The logistic distribution was chosen for computational convenience.

The structural form of the stochastic model is more important for the second conceptual group, those who have not yet entered substance abuse treatment, but who may do so in the future. Let t represent the time from initiation of hardcore heroin use until entering treatment for the first time. Using

[2] The interview (1989 and 1990) only asks about the total number of treatment episodes. It does not ask about the number of treatment episodes during the specific period of interest here.

the generalized gamma family of density functions to represent the distribution of t, f(t), the density function is written:

$$f(t) = \frac{\gamma \mu_j^{\gamma\tau} t^{\gamma\tau-1} e^{-(\mu_j t)^{\gamma}}}{\Gamma(\tau)} \qquad [3]$$

The integral of f(t) from 0 to T is written:

$$F(T) = \int_0^T f(t)dt \qquad [4]$$

where γ, μ_j and τ are parameters to be estimated and $\Gamma()$ is the Gamma function. Covariates enter this specification by writing:

$$\mu_j = e^{\alpha_0 + \alpha_1 MALE_j + \alpha_2 AGE_j + \alpha_3 WHITE_j + \alpha_4 BLACK_j + \alpha_5 MALE_j} \qquad [5]$$

where the α are parameters.

The generalized Gamma function provides a non-monotonic hazard for the first episode of substance abuse treatment, an attractive feature because there is little prior knowledge about what this hazard really looks like. It includes the exponential and Weibull distributions as special cases. It is not too burdensome to compute, although it does require analytical integration, because F(t) has no closed-form equivalent.

Once the first episode of treatment has occurred, by assumption, subsequent episodes of treatment occur according to a poisson process with parameter λ_j. The probability of N_j-1 subsequent treatment episodes, given that one treatment episode has already occurred, is written:

$$P(N_j - 1) = \frac{(\lambda_j T^*)^{N_j - 1} e^{-\lambda_j T^*}}{(N_j - 1)!} \qquad [6]$$

where T* is the time between when the first treatment episode occurred and the time of the interview at T.

Covariates enter into this specification by writing λ as:

$$\lambda_j = e^{\beta_0 + \beta_1 MALE_j + \beta_2 AGE_j + \beta_3 WHITE_j + \beta_4 BLACK_j + \beta_5 MALE_j} \qquad [7]$$

where the β are parameters to be estimated.

Thus, the following parameters require estimation: δ, γ, τ, and the α's and β's. These can be estimated using the method of maximum likelihood, but first some account must be taken of the sampling procedure. Specifically, the sample excludes hardcore users who had been in treatment during the thirty days before the interview, and estimation should proceed conditional on the probability of being eligible for the sample given NJAIL, AGE, WHITE, BLACK, and MALE. A way to approximate this condition is to say that the sample excludes all hardcore users who entered treatment after T-Δ.[3] Because Δ is unknown, we treat it as an additional parameter. With this addition to the model, the likelihood function can be written as:

$$L = \frac{[Q+(1-Q)(1-F(T))]^{I}\left[(1-Q)\int_{t=0}^{T-\Delta} f(t)P(T-\Delta-t)e^{-\lambda\Delta}dt\right]^{1-I}}{Q+(1-Q)(1-(F(T)-F(T+\Delta)e^{-\lambda\Delta}))} \qquad [8]$$

where I=1 when no treatment episodes have occurred and I=0 otherwise.

This likelihood function requires explanation. Ignore the denominator and concentrate on the numerator. When I = 1, no treatment episodes have occurred. The probability of no treatment episodes is equal to the joint probability of none before T-Δ and none after T-Δ, but this is the same as the probability of none before T. The probability of no treatment episodes before T is the sum of the probabilities of two events: A treatment episode will never occur [probability Q] and a treatment episode will occur but has not occurred by T: [(1-Q)(1-F(T))]. This explains the first bracketed term in the numerator.

Now turn to the second bracketed term in the numerator. When at least one treatment episode has occurred (I=0), the probability of observing N_j episodes is the joint probability that all N_j happened before T-Δ and none after T-Δ. The probability of no treatment episode between T-Δ and T (given that at least one has already occurred) is just $\exp(-\lambda\Delta)$. The probability that the first event occurs before T-Δ (according to the Gamma distribution) and the subsequent N_j-1 occur sometime after the first (according to a poisson process) is equal to the rest of the term in brackets. This probability is represented by an integral because there is no closed form equivalent.

Now consider the denominator. The reason for the denominator is that sampling was conditional on the hardcore user's not having been in treatment within thirty days of the interview. Thus, the denominator approximates the probability that the hardcore user had not entered substance abuse treatment within Δ days of the interview. The Δ is a parameter. This completes the description of the likelihood function.

Limitations to the Model

As a representation of how frequently hardcore users seek treatment, this model has limitations. Some are obvious, and others are more subtle.

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[3] This approach assumes that all treatment episodes are the same length, Δ, so that anyone who entered treatment after T-Δ must still be in treatment at the time of the interview. This is only an approximation because, in fact, treatment duration varies across treatment modalities and treatment clients.

Self-reports always have limitations when used to study the behaviors of substance abusers. Substance abusers are sometimes unwilling to report truthfully. At other times, they are unable to report accurately. This is especially likely when they are asked to recall events that happened over many years. Nevertheless, better data are unavailable.

Another obvious limitation is that the NADR data are not necessarily representative of hardcore heroin users. One reason is that interviewers sought IDUs where and when those IDUs could be found -- typically where they purchased their drugs. Those users may differ from others whose purchases and use were less visible.

There is a third reason why the NADR data may not represent hardcore heroin users. The data come from interviews that were conducted in concert with AIDs prevention programs, and the geographic distribution of those programs was not necessarily the same as the geographic distribution of hardcore users. To adjust for this problem, the likelihood function assigned larger weight to interviews completed where hardcore heroin users are most prevalent, and prevalence was based on the Drug Abuse Warning Network (DAWN).[4]

DAWN provides an estimate of emergency room admissions where opiate use is identified as a cause for seeking treatment. By assumption, the number of such admissions is correlated with the prevalence of hardcore heroin use. This correlation is imperfect, because factors in addition to the prevalence of hardcore heroin users account for emergency room admissions. However, the correlation should be sufficiently strong to justify this approach as being an improvement over using unweighted data.

Another obvious limitation is that the model rests on an assumption that treatment availability and treatment-seeking behaviors are constant over time and place. This is untrue. Treatment availability varies with government funding decisions. Treatment-seeking behaviors vary with incentives, including the price of heroin and legal pressures. Measuring this variation is difficult, as is accounting for it in the stochastic model.[5]

The analysis used covariates to partly adjust for this variation. Most IDUs begin heroin use as young adults, so AGE is a proxy for temporal variation in the availability of treatment and treatment-seeking behavior. Incarcerated IDUs have different incentives and opportunities to be treated than those free on the street. The variable NJAIL is a measure of time spent in jail and prison, but only for the most recent five years.

A more subtle problem stems from assuming that a poisson process accounts for the timing of treatment episodes after the first episode. To explain this problem, it is useful to anticipate findings reported later and show the predicted and actual distribution of treatment episodes. These distributions are shown in Figure A1-1.

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[4] A similar argument can be made that the NADR projects interviewed nonrepresentative samples according to race and sex. We have not adjusted for those problems, except by including covariates for gender and ethnicity.

[5] If variables such as treatment availability and the price of heroin could be measured, they could be included at time-varying covariates. However, this modification would greatly complicate the modeling. The issue is moot, at any rate, because such variables are not available for the span of time involved in this analysis.

Many hardcore heroin users have never been in treatment, and the model does a good job of accounting for them. Fewer hardcore users have been in treatment once or twice, and the model does not do as good a job of representing them: it predicts fewer hardcore users with one and two treatment episodes than appear in the data. In contrast, the model overpredicts subsequent treatment episodes.

What is the problem? Apparently, the poisson process understates the frequency of zero and one treatment episode (following the first) and overstates the frequency of two and more treatment episodes (following the first). An alternative approach might be to assume a different stochastic process for the time between the first and second treatment episodes, between the second and third, and so on. However, such assumptions greatly complicate the mathematics and computing, because adopting these assumptions requires the numerical computation of a double, triple or higher-level integral depending on the number of different stochastic processes adopted. It was deemed prudent to consider the model described above as adequate for present purposes.

Finally, it seems likely that the variables NJAIL, AGE, WHITE, BLACK, and MALE fail to capture all the variation across hardcore users. Additional heterogeneity across users might be accounted for with additional covariates or by introducing a term to represent unmeasured heterogeneity (along with its population distribution). We have not pursued that elaboration.

Getting Population Estimates of P

Accepting the model specified above, the expected number of treatment episodes during the year before the interview can be estimated once the parameters are estimated. Let p_j represent the probability that a hardcore heroin user with characteristics AGE_j, $NJAIL_j$, $BLACK_j$, $WHITE_j$, and $MALE_j$ will be eligible to be interviewed, that is, that he or she will not be in treatment during the thirty days before T. This is just the term that appears in the denominator of the likelihood function. Let w_j be a weight such that $w_j=(1/p_j)/\text{sum}(1/p_j)$. These weights sum to 1 over the sample and assign larger weights to sample members who have the lowest probability of appearing in the sample. This weighting is necessary because the sample overrepresents those hardcore heroin users who have the lowest probability of entering treatment.[6]

Then the expected number of treatment episodes during the one-year period before the interview is estimated as:

$$E(N) = \sum_{j=1}^{J} w_j \left[(1-Q)F(T_j-1)\lambda + (1-Q)\int_{t=0}^{1} f(T_j-1+t)\{1+\lambda(1-t)\}\,dt \right] \qquad [9]$$

The first term in brackets is the probability that the first treatment episode occurred before T-1, that is, at least one year before the interview date, multiplied by the rate at which subsequent treatment episodes are generated, that is, lambda. The second term is more complicated. Here, f() is the density function for occurrence of the first treatment episode between T-1 and T, and lambda is the rate at which subsequent treatment episodes occur after this first one. The weights, w_j, adjusts the representation in the population relative to representation in the sample. Thus, E(N) is an estimate for the population.

Similarly, the probability of entering substance abuse treatment during the year before the interview is written.

[6] This weight also is adjusted so that the NADR sample has the same geographic distribution as the DAWN sample.

$$P = \sum_{j=1}^{T} w_j [1 - Q - (1-Q)F(T_j - 1)e^{\lambda} - (1-Q)(1-F(T_j))] \qquad [10]$$

To explain [10], the formula computes the probability of having zero treatment episodes during the one-year period before the interview and subtracts this probability from 1. There are three ways that a hardcore user could have no treatment episodes during the one-year period running from T-1 to T. First, he has a probability of Q of never entering treatment. Second, he has a probability of $(1-Q)F(T_j-1)e^{\lambda}$ of entering treatment before T_j-1 but not during the period T_j-1 to T_j. Third, he has a probability of $(1-Q)(1-F(T_j))$ that his first treatment episode will occur sometime after T_j. This explains the reasoning behind equation [10].

Results from Estimation

Regression results are summarized in Table A1-1. The table identifies the parameter in the third column, says what variable is associated with that parameter (if any) in the second column, gives the parameter estimates in the second column, and reports an asymptotic p-value in the last column. The asymptotic p-value is based on a test of the null hypothesis that the α and β parameters are zero and that the γ and τ parameters are one. The latter hypothesis is appropriate: The model reduces to the Weibul when $\tau = 1$, to the two-parameter Gamma distribution when $\gamma = 1$, and to the exponential when $\gamma = \tau = 1$.

TABLE A1-1

Regression Results: The Number of Treatment Episodes During a Career of Heroin Addiction

Parameters	Variable	Parameter Estimates	P-Values
$\beta 0$	CONSTANT	0.7823	0.00
$\beta 1$	NJAIL	0.3975	0.00
$\beta 2$	AGE	-1.6136	0.00
$\beta 3$	MALE	-0.0993	0.00
$\beta 4$	WHITE	-0.0845	0.00
$\beta 5$	BLACK	-0.4467	0.00
$\alpha 0$	CONSTANT	-1.8372	0.00
$\alpha 1$	NJAIL	-0.0045	0.36
$\alpha 2$	AGE	-3.4196	0.00
$\alpha 3$	MALE	-0.0939	0.00
$\alpha 4$	WHITE	-0.0095	0.24
$\alpha 5$	BLACK	-0.0142	0.15
γ		34.5049	0.00
τ		0.0327	0.00
δ		0.0748	0.00
Δ		0.0006	0.44

Source: NADR 1989 through 1990

Looking at Table A1-1, recall that delta is interpreted as an adjustment for excluding IDUs who had been in treatment within thirty days of the interview. Delta is so small in each of the regressions that the adjustment plays no important role in the analysis. Although this finding is counterintuitive, it might be explained by interviewees' incentives to deny recent (or even current) substance abuse treatment to be eligible for an interview stipend.

In all regressions, the size of the first conceptual group -- those who have a zero probability of ever entering substance abuse treatment -- is small (0.07). This finding seems reasonable. The criminal justice system as well as friends and family provide incentives and sometimes coercion for users to enter treatment. Most likely, only a small group of hardcore users are totally immune from such pressure.

Turning to the second conceptual group, evidence is consistent with the hypothesis that time until the first treatment episode has a gamma density function. This density function reduces to the Weibul when $\tau=1$, but a test on the hypothesis that $\tau=1$ is rejected. It reduces to a two-parameter Gamma when

$\tau=1$, but again, this null hypothesis is rejected. On average, hardcore users wait 11.7 years before entering treatment. Once they have entered treatment for the first time, subsequent treatment episodes happen every 1.1 years.

Although these estimates may or may not seem plausible, any judgement should recognize that the estimates are conditional on the hardcore user's being active (not in recovery) at time T. This is an important point. These estimates are based on retrospective accounts of people who were hardcore users at the time of the interview. A prospective accounting of treatment episodes would not necessarily result in the same estimates, because a prospective account would include people who recovered or were in recovery from drug use. For present purposes, this conditioning is altogether appropriate and desirable, because interest is focused on treatment episodes attributable to current hardcore drug users.

It is interesting, then, to compare these results with self-reports by individuals who are currently in treatment. The Drug Services Research Survey[7] reports the previous treatment history of 292 subjects who were discharged from methadone maintenance between September 1, 1989, and August 31, 1990. By assumption, all of these subjects were hardcore heroin users. They experienced an average of 1.4 treatment episodes in the twelve-month period before entering methadone maintenance. Over a longer period, they reported an average of 3.4 treatment episodes over an average of 5.9 years -- or roughly 0.58 per year. (Bigel Institute, 1991, Table 25).

Our own estimate, based on the analysis reported here, is that hardcore heroin users generate about 0.52 treatment episodes per year per user. This number is considerably smaller than the estimate based on DSRS data for treatment episodes during the month before entering methadone maintenance. Our estimate is closer to the long-term rate for these 292 subjects.

Our estimate is not as close as we might expect. One explanation may be that the estimate based on the DSRS data includes self-help as a treatment mode; our estimate excludes self-help, so it would be smaller than that based on the DSRS data. Another explanation is that the DSRS estimate is conditioned on the fact that a treatment episode has occurred at the end of the one-year period. This would cause the DSRS estimate of treatment episodes to be larger than our estimate. Indeed, we estimate that hardcore users generate 1.44 treatment episodes per year conditioned on their having had at least one treatment episode before that year. This estimate is very close to that reported in the DSRS survey. Thus, the DSRS survey provides some independent evidence that our estimates are reasonable.

For present purposes, the more important statistic is the probability that a hardcore heroin user generates a treatment episode during a given year. Applying formula [10], the probability of a treatment episode during 1989 or 1990 is about 0.33. We use this estimate in the next section.

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[7] The Drug Services Research Survey (DSRS), conducted in 1990 by the National Institute on Drug Abuse (NIDA), provides data on the characteristics of treatment facilities and clients in treatment. The DSRS data provides national estimates of the number of clients in treatment, capacity rates, utilization rates, as well as information concerning waiting lists, modality of treatment, unit ownership, staffing patterns, and demographics of clients.

The DSRS survey is conducted in two phases. The first phase collects facility-level data, while the second phase focuses on clients characteristics. The facility-level data was collected once with a point prevalence date of March 30, 1990 using a stratified random sample of 1,183 drug treatment facilities. Client-level treatment data was collected once using a sample of 2,202 records of clients discharged between September 1, 1989 and August 31, 1990. On-site abstraction of sampled client records took place in 120 facilities.

Bigel Institute for Health Policy, *Drug Services Research Survey: Phase I Final Report: Non-Correctional Facilities* (Brandeis University, September 19, 1991).

Estimating M

Citing statistics provided by the Department of Health and Human Services, the Office of National Drug Control Policy estimates that an unduplicated account of about 1.6 million people were treated for drug abuse during 1989 and 1.5 million were treated during 1990. (Table A1-2 shows estimates for other years.)

TABLE A1-2

Number of People Treated for Drug Abuse, 1989-1994
(thousands)

	1989	1990	1991	1992	1993	1994
Number of persons served	1,557	1,509	1,491	1,455	1,443	1,412

Source: ONDCP, *National Drug Control Strategy: Reclaiming our Communities from Drugs and Violence* (Washington, D.C., February 1994), Appendix B.

Assuming that 1,550,000 individuals entered drug abuse treatment during each year of interest here (1989 and 1990), about how many of them were hardcore heroin users? This question is difficult to answer with precision. The DSRS survey extracted the treatment records of 2220 clients who were dismissed from substance abuse treatment between September 1989 and August 1990. For 6.1 percent, heroin was the "drug of choice" at the time of admission, but this is surely too low of a percentage of the 1.55 million enrolled in drug treatment. One reason is that *alcohol* was the drug of choice for 38.7 percent of the DSRS sample, so heroin users comprise more than 6.1 percent of clients treated for drug abuse. A second reason is that the drug of choice was unknown for 26.5 percent of the DSRS sample.[8] Some adjustment is necessary before the DSRS data are useful for estimating the percentage of treatment episodes attributable to heroin users.

Thus, the first adjustment is to eliminate all client records from programs that only treat alcohol abuse. This eliminates 350 clients, 86 percent of whom selected alcohol as the drug of choice, and 14 percent of whom had an unknown drug of choice (but presumably it was alcohol). Of the remaining clients, all who received methadone maintenance were assumed to prefer heroin over other drugs. For the other treatment modalities, we assumed that the percentage of those who preferred heroin was the same for the unknown category as for the known category. This led to an estimate that 10.9 percent of all those treated for drug abuse selected heroin as their "drug of choice." Applying this 10.9 percent to the 1.55

[8] Curiously, the drug of choice was reported as unknown for 51.8 percent of those receiving methadone, a treatment that is reserved for heroin addicts.

million drug treatment episodes, we estimate that 169,000 hardcore heroin users were treated in both 1989 and 1990.

A problem with the above calculation is that it is based on a treatment population at one point in time. An alternative approach that overcomes this problem is to apply the percentage of heroin addicts treated in each treatment modality (from DSRS) to the number of discharges during 1990 (from NDATUS).[9] The resulting calculation suggests that hardcore heroin users are 12.4 percent of the admissions population.[10] That is, they account for 12.4 percent of all treatment episodes. Based on this percentage, we estimate that 192,000 hardcore heroin users received treatment in both 1989 and 1990.

Estimating H

Applying equation [1], we estimate that a hardcore heroin addict had a probability of 0.33 of entering treatment in 1989 and in 1990. If the estimates are correct that 169,000 or 192,000 hardcore heroin users entered treatment in both 1989 and 1990, then there must have been about 508,000 hardcore heroin addicts according to the first calculation (based exclusively on DSRS data) and 582,000 hardcore heroin users according to the second calculation (based on the DSRS and NDATUS data).

These estimates may understate the number of hardcore users. Recall that the statistical model predicts fewer hardcore users as having one and two previous treatment episodes than actually occur in the data. It predicts more hardcore users as having four and more previous treatment episodes than actually occur in the data. These apparent biases pertain to treatment episodes over the course of the drug use career. Because P is an estimate of the probability of entering treatment during 1989/1990, when many older hardcore users have already experienced a treatment episode, we might expect that the statistical model overestimates P. The estimate P appears in the denominator of formula [1], so an estimate of H may be too small.

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[9] The National Drug and Alcoholism Treatment Unit Survey (NDATUS), a joint effort between the National Institute on Drug Abuse (NIDA) and the National Institute on Alcohol Abuse and Alcoholism (NIAAA), is a national survey designed to measure the location, scope, and characteristics of drug abuse and alcoholism treatment and prevention facilities throughout the United States. Unlike the DSRS survey, the NDATUS survey collects data only on units, not individuals. Treatment units report data on types and scope of services provided, numbers of clients, clients diagnoses, capacity, client demographics, other client characteristics, staffing, and sources of funding. The NDATUS survey has been conducted periodically since 1974, and annually since 1988. A total of 11,277 units responded to the 1991 survey which was conducted as of the point-prevalence date of September 30, 1991.

U.S. Department of Health and Human Services, Public Health Service, Substance Abuse and Mental Health Services Administration, *National Drug and Alcoholism Treatment Unit Survey (NDATUS): 1991 Main Findings Report* (DHHS Publication No. (SMA) 93-2007, 1993).

[10] Although the NDATUS estimates are based on a discharge population, this will approximate an admission population when the number of admissions equals the number of discharges. The constant number of people who receive treatment, as reported by ONDCP, suggests that admissions and discharges are about the same.

These estimates are imprecise for several reasons. It is deceptively difficult to know the number of people who enter substance abuse treatment in a single year, and even harder to know what percentage of them are treated for heroin abuse. It is at least as difficult to estimate the rate at which hardcore heroin users generate treatment episodes. Nevertheless, it is comforting to see that the estimates are close to the estimates reported in the main report. According to Table 1, there were roughly 601,000 hardcore heroin addicts in the United States in 1989 and 533,000 in 1990. We are aware of only one other national estimate of the number of heroin addicts, by Hamill and Cooley,[11] who concluded there were 640,000 to 1.1 million heroin addicts in 1987.

[11] D. Hamill and P. Cooley, *National Estimate of Heroin Prevalence 1980-1987: Results from Analysis of DAWN Emergency Room Data* (RTI Report, Triangle Park, N.C.: Research Triangle Institute, 1990).

APPENDIX 2

ESTIMATING TYPICAL EXPENDITURES ON DRUG CONSUMPTION

This appendix discusses the methodology used to develop estimates of weekly expenditures on cocaine and heroin by arrestees who used either or both of these drugs on more than 10 days during the month before their arrests. The estimates reported here are based on self-reports by arrestees in 24 cities. These self-reports, which are for 1989 and later, are from the Drug Use Forecasting (DUF) program.[1]

The Data

DUF respondents reported how much they spent on *all* drugs combined (during a typical week) but not how much they spent on each individual drug. They also reported the number of days they used any of 22 kinds of drugs during the month before their interview. We used regression analysis to infer expenditure patterns for cocaine and heroin based on these data.

The greatest obstacle to accurate reporting is a respondent's denial of drug use.[2] Therefore, drug use is underreported. Once a respondent admits drug use, however, he or she would seem to have less incentive to underreport or overreport consumption. To be included in this analysis, the respondent had to have admitted some illicit drug use during the last 30 days and had to have admitted some drug expenditure during the typical week. (These different time periods were required because of the wording of the DUF questions.) We estimated expenditure patterns for each year separately.

The dependent variable (EXPEND) was the weekly expenditure on all drugs. This variable was skewed (a few individuals reported very high amounts). Consequently, weekly expenditure was converted to a logarithm before estimating the regression. We then converted the predictions back to the original dollar scale.

The number of days that a respondent consumed each of four categories of drugs were the independent variables. We collapsed drugs into four general categories: COCAINE (powdered and crack), HEROIN (black tar and other), MARIJ (marijuana and hashish—combined in the DUF interview), and OTHER. Cocaine, heroin, and marijuana were the only drugs consumed by a large percentage of the arrestee population. OTHER comprised a large number of infrequently consumed substances. Except for MARIJ, each variable comprised at least two drugs.

The category variable represents the maximum number of days any one of those drugs was consumed. For example, if powdered cocaine had been consumed on 15 days and crack cocaine had been consumed on 20 days, then COCAINE was coded as "20 days."

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[1] No question was asked about the amount of expenditures on drugs in the 1988 DUF data, so no analysis was performed for that year.

[2] Drug users also have difficulty recalling how often they used a drug, how much they used, and how much they paid for it. However, this inaccuracy, unlike intentional denial or deception, probably averages out when the data are aggregated.

We expected the relationship between expenditures and days of consumption to be nonlinear, but the logarithmic translation may not have been adequate to capture that nonlinearity. Consequently, each of the above category variables was raised to the second power, creating additional independent variables: COCAINE2, HEROIN2, MARIJ2, and OTHER2.

Cocaine, heroin, and other drugs are frequently consumed in combination. For example, heroin users often use cocaine, a stimulant, to moderate the effect of heroin, a depressant. However, someone who uses a combination of heroin and cocaine on a daily basis is unlikely to consume the same amount of heroin and cocaine that is consumed by two people who are daily users and exclusive in their drug use.

Consequently, two interaction terms were added to the regression. COKEHER equals COCAINE x HEROIN. COKEHER2 = COKEHER^2/300. The division by 300 facilitates the computing algorithm, but otherwise has no substantive importance for the analysis. The consumption of other drugs was relatively infrequent, so we did not add an interaction term to the regression for this variable.

Starting in 1990, DUF respondents were asked whether they had consumed any drugs in addition to those listed in the interview. A variable OTHERDRG denotes that some other drug had been consumed (1=yes, 0=no). This question was not asked during 1989.

Estimation

We used ordinary least squares to estimate the regressions. Results are presented in Table A2-1.

Table A2-1

Statistical Results for Regression Analysis of Drug Expenditures, 1989-1990

Descriptive Analysis

Variable	1989 Mean	1989 Standard Deviation	1990 Mean	1990 Standard Deviation
EXPEND	4.8	1.6	4.7	1.6
COCAINE	13.0	12.2	11.0	11.8
COCAINE2	316.8	382.5	258.2	361.7
HEROIN	5.0	10.6	4.7	10.3
HEROIN2	137.0	311.9	127.1	301.8
MARIJ	5.7	9.2	4.9	8.6
MARIJ2	118.3	262.9	97.9	242.5
OTHER	2.6	7.3	2.7	7.3
OTHER2	59.7	205.1	61.1	206.1
COKEHER	79.7	231.8	64.8	210.2
COKEHER2	200.2	669.5	161.2	601.9
OTHERDRG	0.2	0.4	0.2	0.4

Regression Results

Variable	1989 Parameter	1989 T-Score	1990 Parameter	1990 T-Score
CONSTANT	3.4444	93.66	3.504	123.42
COCAINE	0.1185	18.61	0.110	21.54
COCAINE2	-0.0014	-7.04	-0.001	-6.84
HEROIN	0.1177	9.64	0.118	11.88
HEROIN2	-0.0001	-3.50	-0.002	-4.63
MARIJ	-0.0179	-2.85	-0.041	-7.55
MARIJ2	0.0009	3.92	0.002	9.09
OTHER	0.0435	4.56	0.058	7.68
OTHER2	-0.0008	-2.29	-0.001	-4.47
COKEHER	-0.0047	-9.36	-0.004	-8.81
COKEHER2	0.0009	5.70	0.001	4.46
OTHERDRG	0.0330	0.84	0.020	-0.65
R-Square	0.4		0.42	
Number of Cases	6,104		8,907	

Source: DUF 1989 through 1990

Table A2-1 (continued)

Statistical Results for Regression Analysis
of Drug Expenditures, 1991-1993

Descriptive Analysis

Variable	1991 Mean	1991 Standard Deviation	1992 Mean	1992 Standard Deviation	1993 Mean	1993 Standard Deviation
EXPEND	4.7	1.5	4.7	1.5	4.7	1.5
COCAINE	11.9	11.9	12.2	12.0	11.9	12.1
COCAINE2	283.4	371.2	294.6	373.9	286.9	372.7
HEROIN	3.7	9.3	3.9	9.5	4.3	9.9
HEROIN2	100.9	273.7	106.4	280.6	115.9	289.7
MARIJ	4.8	8.6	5.5	9.2	6.1	9.7
MARIJ2	96.3	239.6	115.4	263.0	132.1	279.6
OTHER	2.3	6.8	2.3	6.9	2.7	7.4
OTHER2	51.9	193.7	52.5	193.3	61.8	208.4
COKEHER	58.3	202.3	61.0	205.7	59.4	201.5
COKEHER2	147.7	582.5	153.4	590.4	147.1	575.0
OTHERDRG	0.2	0.4	0.2	0.4	0.2	0.4

Regression Results

Variable	1991 Parameter	1991 T-Score	1992 Parameter	1992 T-Score	1993 Parameter	1993 T-Score
CONSTANT	3.4261	128.48	3.4223	128.66	3.4805	128.88
COCAINE	0.1130	23.70	0.1145	24.47	0.1093	22.96
COCAINE2	-0.0012	-7.98	-0.0013	-8.95	-0.0013	-8.53
HEROIN	0.1196	11.68	0.1126	10.81	0.0962	10.23
HEROIN2	-0.0015	-4.56	-0.0014	-4.03	-0.0010	-3.20
MARIJ	-0.0231	-4.58	-0.0139	-2.83	-0.0226	-4.73
MARIJ2	0.0012	6.69	0.0009	5.11	0.0012	7.08
OTHER	0.0535	6.86	0.0545	7.06	0.0421	5.84
OTHER2	-0.0011	-3.88	-0.0011	-4.08	-0.0006	-2.45
COKEHER	-0.0035	-8.04	-0.0032	-7.66	-0.0031	-7.82
COKEHER2	0.0005	3.71	0.0004	3.22	0.0005	3.53
OTHERDRG	0.0168	0.59	0.0187	-0.67	-0.0779	-2.74
R-Square	0.41		0.40		0.39	
Number of Cases	9,872		10,357		9,584	

Source: DUF 1991 through 1993

The model's explanatory power appears remarkable given the presumed measurement error in these data. Residuals were plotted against the number of days that the respondent reported using cocaine, heroin, marijuana, other drugs, and the interaction term. These plots indicate that the logarithmic transformation does a sufficient job of inducing normality among the residuals and that the model specification does not systematically distort the relationship between days of use and amount of money spent.

Interpretation

We converted predictions based on the regression reported in Table A2-1 from logarithms to natural units using two approaches. When Ln($) is the predicted value of the original regression, then the median value in the original units is Median($) = Exponential(Ln($)), and the mean value in the original units is Mean($) = Exponential(LN($)+$\sigma^2/2$).

When cocaine is the only drug consumed, estimating expenditures on cocaine is straightforward. First, substitute zeros for all independent variables other than COCAINE and COCAINE2. Second, use the regression results to make predictions when COCAINE = 1, COCAINE = 2, ... COCAINE = 30. Similar calculations yield estimates for expenditures on heroin when heroin is the only drug consumed.

For example, when cocaine is consumed 10 days a month, the median weekly expenditure is somewhat more than $80. It is about $200 a week when cocaine is consumed on 20 days a month, and it is about $300 a week when cocaine is consumed on 30 days a month.

When broken down by daily expenditure, spending on heroin and cocaine is about the same. However, this does not mean that when cocaine and heroin are consumed in combination, expenditures on each are equally divided. More likely, one of the drugs is the drug of preference, and the other is used frequently, but at a lower dosage.

When cocaine and heroin were consumed in combination, we attributed greater expenditure to what appeared to be the dominant drug. Let $ represent the predicted dollar expenditure on drugs by individuals who consume cocaine and heroin, but no other drugs.

Let N_c represent the number of days a month that an individual consumed cocaine, and let N_h represent the number of days a month that individual consumed heroin. Expenditures on cocaine and heroin are estimated as:

$$\$_c = \$ \left[\frac{N_c}{N_c + ADJ \cdot N_h} \right] \qquad \$_h = \$ - \$_c$$

where ADJ = 0.5 when $N_c > N_h$ and ADJ = 2.0 otherwise. According to this formulation, when cocaine is consumed on more days than heroin, at least two-thirds of the drug expenditure is attributed to the purchase of cocaine. When heroin is consumed on more days (or the same number of days) as cocaine, then at least two-thirds of the drug expenditure is attributed to heroin. As a practical matter, this rule dictates that respondents who say that they use both heroin and cocaine daily spend two-thirds of the money on heroin and one-third on cocaine. This division seems appropriate given evidence that such individuals typically are long-established heroin users who add a small amount of cocaine to their consumption.[3]

[3] D. Hunt, "Tracking the Prevalence of Heroin Use," paper prepared for ONDCP, July 1992.

Typical Expenditures

Using results from the above regression, coupled with assumptions about how joint expenditures on heroin and cocaine should be apportioned, we estimated the median and mean expenditures for cocaine and heroin for every respondent who used either drug heavily. We averaged those estimates over all respondents who admitted using cocaine or heroin on more than 10 days during the month before their arrest. Results are reported in Table A2-2.

Typical expenditures appear to have remained stable over time. The chief problem in interpreting these numbers is that the medians are so different from the means. Which should be used as "typical" expenditures? Evidence presented later seems to indicate that the median is preferable. Before turning to this evidence, the matter of earnings from income in kind must be considered.

TABLE A2-2

Mean and Median Expenditures on Cocaine and Heroin, 1989-1993

	1989	1990	1991	1992	1993
Expenditures on cocaine by those who use cocaine heavily					
(Mean)	$474	$488	$450	$440	$394
(Median)	$228	$240	$230	$219	$206
Expenditures on heroin by those who use heroin heavily					
(Mean)	$566	$575	$535	$486	$459
(Median)	$277	$283	$273	$242	$240

Source: DUF 1989 through 1993.

Accounting for Income in Kind

Hardcore drug users support their drug use through legitimate sources and through crime, especially drug dealing. Returns from dealing are often in the form of drugs as a payment for services rendered, or "income in kind." How does income in kind affect our estimates?

It is sometimes asserted that most hardcore users pay for their drug use by dealing or assisting others who deal in illicit substances. For example, Johnson and colleagues[4] report that in their sample of New York City heroin users, daily users spent an average of $7,601 a year on heroin, but consumed about $13,189 worth of heroin a year. Regular users (defined in this study as those who use heroin between three and six times a week) spent $4,019 a year on heroin, but consumed about $6,431 worth of the drug a year. The difference between expenditures and consumption represents in-kind earnings in the form of drugs. If this were a typical pattern, then the expenditures on drugs computed from DUF should be

[4] B. Johnson et al., *Taking Care of Business: The Economics of Crime by Heroin Abusers* (Lexington, Massachusetts: Lexington Books, 1985).

inflated by ($13,189/$7,601) or 1.73 for daily users, and ($6,431/$4,019) or 1.6 for regular users. For reasons reported here, such multipliers seem much too large.

First, consider a hypothetical illustration of a drug market. Suppose that mid-level dealers have 100,000 units of drug X to sell and, at $1 a unit, demand $100,000 for their drugs. Suppose initially that there are 100 hardcore users, but no other users. Then, each hardcore user must generate $1,000 of income for the mid-level dealers.

The 100 hardcore users could support their use partly from dealing, but clearly they cannot support their use entirely from dealing. Selling exclusively to each other would not raise the $100,000 expected by mid-level dealers. The $100,000 must come from some other source.

Now, these 100 users could support one-third of their consumption by selling 66,666 units for $1.50 a unit to each other. This is a Pyrrhic marketing success, of course, but it would be effective if alternative income sources sometimes provided sufficient funds to make purchases and sometimes did not. The total revenue generated is $100,000, enough to satisfy the middlemen. This division of drugs would approximate what was observed by Johnson and colleagues in New York.

This solution requires that the street price of drug X be 50 percent higher than the price to mid-level dealers. In reality, retail prices for cocaine and heroin are about one-third higher than wholesale prices,[5] so income in kind would seem more likely to add about 33 percent to our estimates of drug consumption based on transactions in which money was exchanged.

Moreover, many sellers do not themselves consume drugs (at least not at heavy-use rates). To extend the above illustration, suppose that one-half the 100,000 units of drug X are sold by entrepreneurs who do not themselves consume drugs. Then, the 100 hardcore users could support only about 17 percent of their own drug use by selling drug X at $1.5 a unit to other users. The market opportunities for hardcore users to support their own consumption with income in kind is limited by sales by nonusers. Sales by nondrug users may be sizable.

Reuter and colleagues report that only 11 percent of the dealers they interviewed retained one-half or more of the drugs for personal consumption; 30 percent retained less than one-half, "usually only 'a little of it.'"[6] If "a little of it" means 15 percent, then these figures suggest that about 10 percent of the drugs that were available to these dealers were retained for personal consumption. If Reuter's dealers are typical of those who sell drugs, then the expenditure figures based on dollar transactions should be increased by 0.1/0.9, or about 11 percent to account for income in kind.

In his field study, conducted in 1982 and 1983, of 15 street-level heroin dealers in Detroit, Mieczkowski[7] reports that dealers are typically not hardcore users: "...although runners appear by and large to be recreational drug users, they are not addicted to heroin." Mieczkowski's findings suggest that income in kind represents a smaller percentage of drug consumption than was reported by Johnson.

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[5] W. Rhodes, R. Hyatt, and P. Scheiman, "The Price of Cocaine, Heroin, and Marijuana, 1981-1993," *Journal of Drug Issues*, 24, no. 3. (1994): 383-402.

[6] P. Reuter et al., *Money from Crime: A Study of the Economics of Drug Dealing in Washington, D.C.* (Santa Monica, California: Rand Corporation, 1990) RAND publication R-3894-RF, p. 61.

[7] T. Mieczkowski, "Geeking Up and Throwing Down: Heroin Street Life in Detroit," *Criminology*, 24, no.4. (1986): 645-665.

Altschuler and Brounstein[8] interviewed 387 ninth and tenth grade, minority, inner-city boys from Washington, D.C., during 1988. Of the 387, 7 percent used drugs, but did not sell them; 9 percent sold drugs, but did not use them; and 4 percent both sold and used drugs. These findings suggest that many drug sales are made by dealers who are not hardcore users.

Williams tracked the drug (cocaine and crack) dealing of eight New York juveniles who belonged to a teenage drug ring called the Cocaine Kids, or the Kids. Williams reports that "...virtually all cocaine suppliers expect retail dealers to return with cash amounting to about 60 to 75 percent of potential retail sales of their consignment."[9] If this profit margin is typical for cocaine and crack retailers, and if all this profit is income in kind spent on the retailer's consumption, then estimates based on dollar transactions might be multiplied by 0.66 to 0.33. However, the dealers interviewed by Williams did not take their profits primarily in the form of crack: "All the Kids snort cocaine regularly. This is accepted, but the use of crack is generally frowned upon: those who snort are thought to have more control and discipline than those who smoke crack or freebase. Most dealers see crack smokers as obsessive consumers who cannot take care of business; crack users, they say, tend to become agitated, quickly lose control and concentration, and take one dose after another at the expense of everything else."[10]

Skolnick,[11] who examined crack sales by gang members in California during 1988, reports two types of dealers: one who sells for profit and one who sells to buy drugs. Interestingly, Skolnick also reports that 75 percent of street sales will be returned to the middleman, a figure consistent with that reported by Williams in New York.

Waldorf and Lauderback interviewed 568 members of 86 different ethnic gangs in San Francisco.[12] They reported that only 16 percent of the crack sellers used crack during the month before the interview, although about one-half of the cocaine sellers and about three-fourths of the heroin sellers used those drugs during the month before the interview. The gang members explained that intoxicated sellers did not make reliable dealers and that drug dependence impaired the gang member's ability to defend the gang. Waldorf and Lauderback reached similar conclusions to Chin[13] (Chinese gang members who sold heroin did not use it) and Vigil.[14]

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[8] D. Altschuler and P. Brounstein, "Patterns of Drug Use, Drug Trafficking, and Other Delinquency among Inner-City Adolescents in Washington, D.C.," paper presented at the Annual Meeting of the American Society of Criminology, Reno, Nevada, 1989, 9; and Table 3.

[9] T. Williams, *The Cocaine Kids: The Inside Story of a Teenage Drug Ring* (Reading, Massachusetts: Addison-Wesley Publishing, 1989), 36.

[10] Williams, *The Cocaine Kids*, 47.

[11] J. Skolnick, *The Social Structure of Street Drug Dealing* (BCS FORUM, Office of the Attorney General, State of California, undated).

[12] D. Waldorf and D. Lauderback, "Don't Be Your Own Best Customer – Drug Use of San Francisco Ethnic Gang Drug Sellers," *Crime, Law and Social Change — An International Journal*, 19 (1993): 1-15. The published article was based on a population of 300; however, an updated version surveyed 568 gang members.

[13] K. Chin, "Chinese Triad Societies, Tongs, Organized Crime and Street Gangs in Asia and the United States," unpublished Ph.D. dissertation, University of Pennsylvania, Philadelphia, Pennsylvania, 1986.

[14] J. Vigil, *Barrio Gangs: Street Life and Identity in Southern California* (Austin, Texas: University of Texas Press, 1988).

Mieczkowski, on the other hand, reports that crack sellers in his Detroit sample "appear to conform closely to the 'classic' or 'hustler' view of the drug user."[15] Nearly two-thirds of the respondents said that they sold crack to get money for their own crack consumption.

The important point is that many of the drugs consumed by hardcore users are sold by individuals who do not use drugs heavily. The ability of hardcore users to support their own use through dealing is necessarily limited. Consequently, the amount of drugs that hardcore users receive as income in kind cannot account for much of the cocaine and heroin consumed.

Data are not sufficient to support precise estimates. It seems that a street dealer might be able to retain about one-fourth of the drugs that he markets, and that profit dealers (those taking their profit in cash rather than in kind) are more numerous among cocaine dealers than among heroin dealers. We assume that two-thirds of the cocaine dealers and one-third of the heroin dealers are profit dealers.

Assume that a cocaine retailer must return $3 for every $4 of crack or powdered cocaine that he sells. Also assume that two-thirds of all retail dealers are profit dealers and one-third are users. This means that every $1 spent on crack and cocaine would result in $1 x 0.33 x 0.33 = $0.11 in income in kind, suggesting that the estimates should be inflated by 0.11. This inflation figure equals the 11 percent income in kind figure derived from Reuter and colleagues' study.

Second, assume that a heroin retailer must return $3 for every $4 of heroin that he sells. Also assume that one-third of the retail dealers are profit dealers. This means that every $1 spent on heroin would result in a maximum of $1 x 0.33 x 0.66 = $0.22, suggesting that the estimate should be inflated by 0.22. This inflation figure is lower than the income in kind figure derived from Johnson and colleagues' study but is more consistent with observations that not all those who sell heroin are hardcore users.

We assume a somewhat higher estimate for income in kind. We assume that $0.25 worth of heroin is retained as income in kind for every $1 of heroin sold. For cocaine, we assume one-half that amount, or $0.125, for every $1 sold.

Choosing the Median As the Typical Expenditure

If weekly expenditures on drugs were reported with perfect accuracy, there would be little justification for using any number other than the mean. After all, regardless of how the data are skewed, the mean is the average expenditure, and total expenditures will equal the average expenditure multiplied by the number of hardcore users.

However, another interpretation seems more reasonable. Suppose that the average expenditure is about the same for everybody who uses drugs on a specified number of days a month, but that the amount spent on drugs is reported with great inaccuracy. From this view, the median is the best measure of the average expenditure.[16] Some other sources suggest that the median expenditure is more accurate for our analysis.

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[15] T. Mieczkowski, "Crack Distribution in Detroit," *Contemporary Drug Problems*, (Spring 1990): 23-24.

[16] An analogy helps make this point. Suppose that a grocery store clerk were to ring 1,000 $1 candy bars individually on his register. Suppose that he was inaccurate but unbiased as he occasionally registered too many or too few zeros: 100 bars were priced at $0.10, 800 were priced at $1, and 100 were priced at $10. The total expenditure on candy bars would be $1,810, or an average of $1.81 per candy bar. Here the clerk's random errors do not balance out.

Other reports of expenditures on drug use

Other studies, primarily of hardcore users involved with the criminal justice system, estimate expenditures on heroin and cocaine that are broadly consistent with the medians reported here (Table A2-2).

Johnson and colleagues[17] interviewed 201 subjects who were street-level heroin users in East and Central Harlem; all were involved in some form of criminality and spent most of their time on the streets. Subjects were interviewed for five consecutive days, and then were interviewed weekly for the following four weeks. About 132 of these subjects were interviewed four more times at three- to six-month intervals. The average user spent $4,203 a year on heroin. These users often sold drugs, and when they did, payment was usually in the form of drugs as income in kind. When income in kind was taken into account, these users spent about $6,986 a year on heroin. Daily users directly purchased $7,601 worth of heroin a year, but when income in kind is taken into account, they spent about $13,189. Regular users (those who used at least weekly, but less than daily) made cash payments of $4,019 for heroin over the course of a year, but with income in kind payments, their annual expenditures were $6,431. These estimates are comparable with those based on the median responses in the DUF data, which suggest that hardcore users of heroin spend about $12,000 a year on heroin.

Johnson and Wish[18] recruited 105 male New York "hard-drug abusers" who had committed one or more relatively serious non-drug crimes (such as robbery, burglary, grand larceny, or assault) in the past 24 hours. Those who had committed recent robberies spent an average of $52 a day on illicit drugs. Those who had committed other crimes spent an average of $32 a day. Thus, for those who had just committed crimes, the expenditure on drugs was $224 to $364 a week.

For those who bought both heroin and cocaine, daily expenditures totaled $259 to $357 a week. Those who bought only cocaine spent $175 to $231 a week on cocaine. Those who bought only heroin spent $154 to $252 a week on heroin. It is notable that 86 percent of these subjects reported using some illicit substance on 28 of the past 30 days, so the majority could be considered hardcore drug users. These figures seem to be high estimates of consumption, however. Because all these users had recently committed serious crimes, they had money available from illegal sources to buy drugs. Nevertheless, the average expenditures were about the same as those based on the median values from the DUF data.

Reuter and colleagues report results based on interviews with 186 males on probation in Washington, D.C., who had sold drugs during the mid-1980s. About one-half reported purchasing drugs for their own use. This half had a median expenditure of $400 a month; the mean was $1,596. However, about 40 percent of the respondents consumed some of the drugs that they acquired for dealing, representing income in kind spent on drugs; about 10 percent reported that they consumed one-half the drugs that they acquired by dealing. The median and mean are much smaller than their counterparts in DUF, but the Reuter subjects are not necessarily hardcore users.[19]

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[17] B. Johnson et al., *Taking Care of Business: The Economics of Crime by Heroin Abusers* (Lexington, Massachusetts: Lexington Books, 1985).

[18] B. Johnson and E. Wish, "The Robbery-Hard Drug Connection: Do Robbers and Robberies Influence Criminal Returns and Cocaine-Heroin Purchases," paper presented at the Criminology Section of the American Sociological Association, August 17, 1987.

[19] P. Reuter et al., *Money from Crime: A Study of the Economics of Drug Dealing in Washington, D.C.* (Santa Monica, California: Rand Corporation, 1990) Rand Publication R-3894-RF, p.61.

Mieczkowski[20] asked 190 "chronic users of crack cocaine" in Detroit about their crack consumption by appending questions to the DUF interview. About one-fourth of these users consumed four or fewer rocks[21] a week ($40 or less a week); most of the others clustered at 10 to 20 rocks a week ($100 to $200 a week) and 40 to 50 rocks a week ($400 to $500 a week). Only 5 percent used over 100 rocks a week. Mieczkowski speculated that the upper range included dealers who could not distinguish between their own consumption and what they sold, as well as individuals who were sharing with friends.

This additional evidence is consistent with the conclusion that the median values based on DUF data typify spending patterns for those arrestees who admitted using cocaine or heroin on at least 11 days during the past month. However, some of the studies described below report larger expenditure patterns.

Mieczkowski[22] reports on interviews with "100 self-reported dealers and user/dealers of crack cocaine" who were in residential treatment facilities in Detroit. All can be considered to be hardcore users. The amounts reported on weekly drug usage were highly skewed. The estimates were: $937 mean; $877 trimmed mean; $600 median; $544 M-estimator. These estimates are considerably higher than those we report, although they are not inconsistent with estimates for the very heaviest users. One explanation of this variation may be that these users had especially high use patterns, as evidenced by their seeking treatment.

Other studies of treatment populations indicate that expenditures can be much higher for the typical hardcore user than is assumed here. Schnoll and colleagues[23] report on expenditures by 172 men and women who received treatment for cocaine abuse in Chicago primarily during 1982 and 1983. Average expenditures were reported as $800 a week.

Gawin and Kleber[24] describe heroin use in a sample of 30 consecutive admissions to a cocaine treatment program in New Haven. Thirteen intravenous drug users used an average of 5.6 grams a week, six smokers used an average of 9.1 grams, and 11 who snorted used an average of 5.3 grams a week. If these users paid $100 a gram, they must have spent $500 to $900 a week for cocaine prior to entering treatment.

Collins, Hubbard, and Rachal (1985) studied annual drug expenditures of 3,276 drug users who entered publicly-funded drug treatment in 1979.[25] For daily heroin users, the median drug expenditure was $10,000, and the mean was almost $16,999. For weekly users (exclusive of daily users), the median was

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[20] T. Mieczkowski, "Crack Distribution in Detroit," *Contemporary Drug Problems*, (Spring 1990): 18-20.

[21] Crack is made by heating powdered cocaine until it crystallizes. "Rocks" are then broken off the chunk of crack produced. Crack is often bought by the rock. Although this purchase unit varies in weight and size, rocks tend to be fairly small and inexpensive.

[22] T. Mieczkowski, "The Economic Dimensions of Crack Use and Distribution: Some Preliminary Data," paper presented to the American Society of Criminology Annual Meetings, Reno, Nevada, November 1989.

[23] S. Schnoll et al., "Characteristics of Cocaine Abusers Presenting for Treatment," in *Cocaine Use in America: Epidemiological and Chemical Perspectives*, ed. N. Kozel and E. Adams (Rockville, Maryland: National Institute on Drug Abuse, 1985), NIDA Research Monograph 61, 171-181.

[24] F. Gawin and H. Kleber, "Cocaine Use in a Treatment Population: Patterns and Diagnostic Distinctions," in *Cocaine Use in America: Epidemiological and Chemical Perspectives*, ed. N. Kozel and E. Adams, (Rockville, MD: National Institute on Drug Abuse, 1985), NIDA Research Monograph 61, 182-192.

[25] J. Collins, R. Hubbard, and J. Rachal, "Expensive Drug Use and Illegal Income: A Test of Explanatory Hypotheses, *Criminology*, 23, no. 4. (1985): 743-763.

$4,000, and the mean was about $7,400. There were fewer regular cocaine users. On a yearly basis, daily users spent a median of $14,000, and a mean of almost $19,000. Those who used on a weekly (but not daily) basis had median expenditures of $6,100, and a mean of almost $12,000.

Comparing these estimates with those based on DUF is complicated. Because these estimates are from 1978 and 1979, an adjustment for inflation would lead to estimates that are higher than those based on DUF. However, the street price of heroin and cocaine have fallen so much since 1978-1979, even controlling for inflation, that 1978-1979 is a questionable benchmark. Another limitation is that cocaine users who sought treatment in the late 1970s may have little resemblance to crack users of the late 1980s and early 1990s.

Although the latter studies, all of which are based on a population in treatment, indicate that hardcore users spend more on cocaine than is assumed in this study, users in treatment probably have use patterns that are atypical of hardcore users in general. As Waldorf and colleagues[26] report, most hardcore cocaine users are able to control their consumption, avoiding the ruinous expenditure patterns that often drive other users — those who have the least control — into treatment.

Evidence from the NHSDA

Additional evidence comes from the NHSDA. The number of individuals who admitted using cocaine on more than 10 days during the month before the interview and reported how much they had spent on cocaine was small, thus the estimates for cocaine expenditures are fairly unreliable (Table A2-3). For example, in 1993, only seventy-eight individuals admitted hardcore cocaine use and reported cocaine expenditures. Average expenditures were $81 a week. These average expenditures reported by hardcore cocaine users in NHSDA were much lower than those reported in DUF (Table 2). Although the NHSDA estimates appear to show a decrease in average expenditures by hardcore cocaine users from 1988 ($130) to 1993 ($81), this trend is neither consistent nor reliable.

TABLE A2-3

Average Expenditures on Cocaine by Hardcore Cocaine Users, 1988-1993

	1988	1990	1991	1992	1993
Average expenditures	$130	$17	$83	$34	$81
Number of valid answers	27	30	119	66	78

Source: NHSDA 1988, 1990 through 1993

Estimates based on amount consumed

[26] D. Waldorf et al., *Cocaine Changes: The Experiences of Using and Quitting* (Philadelphia: Temple University Press, 1991).

Another way to validate the median as a measure of expenditures is to infer how much hardcore cocaine and heroin users could spend given their consumption patterns.

It is difficult to shoot heroin more frequently than four times a day, and many DUF respondents used heroin less often than daily.[27] According to Division of Substance Abuse Services (DSAS) in New York City, a hardcore user might use one to two bags of heroin a session, and each bag would cost $10. These approximations suggest that a hardcore user could not spend much more than $420 a week.

Although $420 is close to the mean expenditure estimated based on the DUF data, even those heroin users who are hardcore consumers cannot shoot heroin every day, four times a day. Clearly, $420 a week should be considered more as an upper limit than an average for weekly expenditure on heroin.

Cocaine is different. While heroin seems to be self-limiting (the user's craving can be satisfied much as a diner is satiated after a full meal), cocaine is notable because it immediately engenders a desire for more cocaine. As discussed earlier, there are reports of very hardcore consumption patterns just prior to seeking treatment.

Nevertheless, cocaine consumption has two limitations. The first is physiological. Binge use exhausts the body, so rest is necessary before binge use can recur. The second is that hardcore cocaine use can quickly exhaust financial resources. One wa to check estimates of drug spending patterns for cocaine is to assess the user's income from legal and illegal sources.

Estimates based on financial resources

One way to assess the practical upper limit for cocaine use (excluding the minority of users who drain personal resources prior to entering treatment) is to estimate the amount of money that hardcore users have available to spend on cocaine.

According to DUF, most hardcore users who are arrested and questioned have limited legal incomes. Much of their earnings comes from crime. How much do such individuals earn from combined sources?

As would be expected, it is no easier to estimate the amount of money earned from crime than it is to estimate the amount of money spent on drugs. There are, however, a few studies of earnings from property crime. Johnson and colleagues, in a study described above, report that daily heroin users earn an average of $8,825 a year from non-drug criminal activity, and regular users earn $6,283 a year. Total criminal income, including drug income in kind, is $18,820 for daily users and $11,203 for regular users. After living expenses are subtracted from these incomes, the amount available for heroin expenditures could not be much greater than is assumed in this report.[28]

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[27] Kahn reports an average of three fixes a day for 453 clients before their participation in a methadone maintenance program. Only 16 percent of his clients reported more than four fixes daily. Anglin reports that during the 12 months before entering criminal justice supervision, 279 heroin addicts (who had been identified through a methadone maintenance program in the early 1970s) had injected heroin an average of 2.7 times a day. R. Kahn, "The Frequency of Narcotic Use Before and After Admission to a Methadone Maintenance Program," *International Journal of the Addictions*, 14, no. 8. (1979): 1157. M. Anglin et al., *Effects of Legal Supervision on Narcotics Use and Criminal Behavior over the Addiction Career* (Los Angeles, CA: UCLA Drug Abuse Research Group, December 1988).

[28] B. Johnson et al., *Taking Care of Business: The Economics of Crime by Heroin Abusers* (Lexington, Massachusetts: Lexington Books, 1985).

Anglin and colleagues[29] describe the income of 279 male heroin addicts who were selected from those who had first entered a methadone program between 1971 and 1973. The period of time described is the 12 months prior to their first period of legal supervision. Chicano respondents averaged $6,708 in illegal income a year (not counting $924 a year from drug dealing), and whites averaged $8,580 a year (not counting $1,320 a year from drug dealing). Legal incomes were $1,984 to $2,672 a year. Even when inflation is taken into account, these incomes could not support drug use habits far in excess of what is assumed in this paper.

Reuter and colleagues report results based on interviews with 186 males on probation in Washington, D.C., who had sold drugs during the mid-1980s. They report an average income of $2,863 a month, all but $849 from illegal activity, mostly drug sales. However, most of this income was spent on expenses other than drugs — drug expenditures averaged $883 a month.[30]

Conclusions

The evidence is not compelling, but it seems best to assume that the median expenditures on cocaine and heroin—as measured from DUF data—provides the best basis for computing dollar expenditures on cocaine and heroin. The uncertainty surrounding this assumption is best handled through sensitivity analysis, which we execute in the main report.

The evidence in support of the percentage of drugs earned as income in kind is also meager. We assume that for every dollar spent on cocaine another $0.125 of cocaine is consumed as income in kind. We assume that for every dollar spent on heroin another $0.25 of heroin is consumed as income in kind.

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[29] M.D. Anglin et al., *Effects of Legal Supervision on Narcotics Use and Criminal Behavior Over the Addiction Career* (Los Angeles, CA: UCLA Drug Abuse Research Group, December 1988); and Table 3.

[30] P. Reuter et al., *Money from Crime: A Study of the Economics of Drug Dealing in Washington, D.C.* (Santa Monica, California: Rand Corporation, 1990), Rand Publication R-3894-RF, p. 61.

APPENDIX 3

DRUG PRICES

Several sources report prices paid for illegal drugs.[1] The problem with those sources, for present purposes, is that they report prices as broad ranges, unsuitable for the calculations used in this report.

Recent studies provide a method for estimating prices within a narrower range.[2] Basically, this methodology is to estimate the price paid during market transactions (completed by police as undercover agents, and hence reported to a data source) using regression analysis to control for the quantity and quality (purity is the measure of quality) of drugs sold. Results from the regression are then used to estimate the price paid on average at a given time and place for a given quantity and quality of drugs.

For this report, we analyzed data from the System to Retrieve Drug Evidence (STRIDE), which were available from January 1981 through June 1994. The data and our basic approach are described elsewhere.[3] We have updated that method for present purposes, and we will report full results at a later date.

One problem when using regression analysis to estimate illicit drug prices is that the typical quantity and quality of drug entering a retail transaction is unknown. As others have noted,[4] retail transactions take so many forms that an average retail price is hard to identify. Nevertheless, the calculations used in this report required one.

We used this approach: Let P = F(Am, Pu) be a functional representation of the relationship between price paid (P) and the amount (Am) and purity (Pu) of drugs purchased. This functional relationship was determined by regression analysis as explained earlier.

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[1] For example: Drug Enforcement Administration, *Illegal Drug Price/Purity Report United States: January 1990-December 1993*, April 1994; National Institute on Drug Abuse, *Epidemiologic Trends in Drug Abuse, Volume II Proceedings*, June 1994.

[2] G. Brown and L. Silvermen, "The Retail Price of Heroin: Estimation and Applications," *Journal of the American Statistical Association*, 69, no. 347 (1974):595-606; J. Caulkins and R. Padman, "Quantity Discounts and Quality Premia for Illicit Drugs," *Journal of the American Statistical Association*,88, no. 423 (1994):748-57; W. Rhodes, R. Hyatt and P. Scheiman, "The Price of Cocaine, Heroin and Marijuana, 1981-1993," *The Journal of Drug Issues*, 24, no. 3 (1994):383-402; J. Caulkins, *Developing Price Series for Cocaine*, MR-317-DPRC (Santa Monica, CA, Rand).

[3] W. Rhodes, R. Hyatt and P. Scheiman, "The Price of Cocaine, Heroin and Marijuana, 1981-1993," *The Journal of Drug Issues*, 24 no. 3 (1994):383-402.

[4] J. Caulkins, "What is the Average Price of An Illicit Drug?" *Addiction*, 89, no. 7 (July 1994): pp. 815-19.

Let $D represent the average dollar amount that a hardcore drug user spends per week on illicit drugs. This number was reported in Table 2 of the main report. Setting Pu equal to the average purity of drugs sold at the retail level, and assuming that the user buys drugs once per week, the typical amount of drugs in a weekly purchase must be the solution to the equation:

$$\$D = Am \cdot F(Am, Pu)$$

If Am* is the solution to this equation, then one estimate of retail prices is F(Am*, Pu).

Similarly, assuming that the user buys drugs at T separate times during the week, the purchase amount must be the solution to the equation

$$\$D = T \cdot Am \cdot F(Am, Pu)$$

If Am** is the solution to this equation, another estimate of retail price is F(Am**, Pu).

Now, if few hardcore users buy drugs less frequently than once per week, and if few heavy users buy drugs more frequently than T times per week, then F(Am*, Pu) and F(Am**, Pu) provide low and high prices, respectively. They are reported as such in the main text.

This price range does not encompass all prices paid at retail. Many hardcore drug users undoubtedly pay much more. Others probably pay much less. These limits are intended to encompass the price that is typically paid at retail. That is, it is a range that seems likely to include the price that hardcore drug users pay on average for retail-level drug transactions. Prices are reported in Table 3 of the main report.

APPENDIX 4

IMPUTATIONS FOR MISSING DATA ON MARIJUANA USE

Calculations of the amount of marijuana used by household members was straightforward. We multiplied the number of marijuana users per month, by the average number of joints smoked per user, by the average weight of a joint. The result was then multiplied by twelve months to give a year's estimate. The principal problems when making this calculation are dealing with missing data and with responses that represent a range. The latter presents a problem because the ranges are not suitable for our calculations. Because the Substance Abuse and Mental Health Services Administration had already imputed responses when there was missing data about recent use, this was not a problem. This appendix explains how we imputed responses when either the number of joints smoked or the amount of marijuana smoked were missing or were reported as a range.

Imputing the Number of Joints Smoked

From the National Household Survey for 1991, analysts selected respondents who said they used marijuana in the past month and who gave valid responses to three related questions. The first question was the number of days they smoked marijuana in the past month (DAYS). Valid responses were 1-30 days. The second question was the number of marijuana cigarettes smoked per day in the past month (JOINTS). From the responses to these two questions, analysts created a variable

TOTAL JOINTS = DAYS*JOINTS.

The third question was the amount of marijuana used during the last month (AMOUNT). This is exactly the question that the analysts sought to answer, but the AMOUNT question was not directly useful for this purpose because it was specified as a range. The acceptable answers to AMOUNT were:

1-10 joints
11-20 joints
1 ounce
2 ounces
3-4 ounces
5-6 ounces

The analysts' problem was to infer the amount of marijuana used by people who said they used marijuana in the last month based on the variables TOTAL JOINTS and AMOUNT.

As short-hand, let J represent TOTAL JOINTS, let A represent AMOUNT, and let W equal the weight of marijuana used in ounces. The analysts wanted to estimate W.

Now, W is unknown, but it might be represented as:

$$W = \lambda J + \varepsilon \qquad [1]$$

where λ is the weight per joint and ε is a random error term, which will be discussed below. Equation [1] says that, on average, a person who smokes J joints will use W ounces of marijuana, because λ is the average weight of a single joint. Of course, some people who smoke J joints use a little less; some use a little more. This variation about what is typical is reflected in the term ε.

Assume that ε is distributed normally with a mean of zero, a standard deviation of σ, and that the error terms are independently and identically distributed. It turns out that these assumptions about the distribution of ε are hard to justify, and alternative assumptions are adopted later. However, this simple, if somewhat unrealistic, specification is useful for explaining the approach.

Although W is unknown to the analysts, it is known to the respondent, and by assumption the value of W determines the respondent's answer for AMOUNT. Specifically, the respondent will say that he used

1-10 joints when	$W \leq \alpha_1$
10-20 joints when	$\alpha_1 < W \leq \alpha_2$
1 ounce when	$\alpha_2 < W \leq 1.5$
2 ounces when	$1.5 < W \leq 2.5$
3-4 ounces when	$2.5 < W \leq 4.5$
5-6 ounces when	$4.5 < W$

The logic here is that the respondent will select the usage category that most closely describes his use, although it seems reasonable to suppose that he makes errors when making this translation. Two terms are unknown, α_1 and α_2. The first, α_1, is presumably the weight of 10.5 joints. The second is harder to interpret, but α_2 is some value that distinguishes the response "10 to 20" joints from "1 ounce," at least in the eyes of the respondent.

There are four parameters to be estimated here: λ, σ, α_1 and α_2. These parameters can be estimated by maximum likelihood once a probability has been assigned to every response. Specifically,

$$P_1 = P\ (1\text{-}10\ joints) = \Phi\left(\frac{\alpha_1 - \lambda J}{\sigma}\right)$$

$$P_2 = P\ (11\text{-}20\ joints) = \Phi\left(\frac{\alpha_2 - \lambda J}{\sigma}\right) - P_1$$

$$P_3 = P\ (1\ ounce) = \Phi\left(\frac{1.5 - \lambda J}{\sigma}\right) - P_1 - P_2$$

$$P_4 = P\ (2\ ounces) = \varnothing\left(\frac{2.5 - \lambda J}{\sigma}\right) - P_1 - P_2 - P_3$$

$$P_5 = P\ (3\text{-}4\ ounces) = \varnothing\left(\frac{4.5 - \lambda J}{\sigma}\right) - P_1 - P_2 - P_3 - P_4$$

$$P_6 = P\ (5\text{-}6\ ounces\ or\ more) = 1 - P_1 - P_2 - P_3 - P_4 - P_5$$

where ϕ is the standard normal distribution function.

This approach is similar to an ordered probit model. There is an important difference between this approach and a traditional probit model, however. Specifically, the threshold values of 1.5, 2.5, and 4.5 are known although α_1 and α_2 are unknown. This allows the parameter σ to be identified and estimated. In turn, this allows λ to be identified and interpreted as the weight of a marijuana cigarette.

One further extension is to assume that:

$$\alpha_1 = \lambda\text{-}10.5$$

That is, the parameter α_1 equals the weight of 10.5 joints, because the weight of 10.5 joints is the threshold value between the responses "1-10 joints" and "11-20 joints." There are only three remaining parameters to estimate: α_2, λ, and σ.

As stated, this model is an unacceptable representation of the relationship between the number of joints smoked and the amount of marijuana smoked. A more convincing model is:

$$W = (\bar{\lambda} + \varepsilon_1)\, J + \varepsilon = \bar{\lambda}J + J\varepsilon_1 + \varepsilon = \bar{\lambda}J + \varepsilon_2 \qquad [2]$$

This implies that the average joint weighs $\bar{\lambda}$ ounces, but that the weight varies across users. This variation is represented by the distribution of ε_1. The model would be complete once the distribution of ε_2 is specified.

The distribution of ε_2 has to satisfy some a priori constraints. First, *W* must be positive, so ε_2 has a lower limit that depends on $\bar{\lambda}J$. Second, the distribution of ε_2 should account for an apparent upward skew:inspection of the data shows that some users seem to use much more than the average amount of marijuana, but nobody can use much less because zero is a lower limit. Third, the error term is heteroscedastic.

A new specification is more useful, given these a priori constraints:
where $\varepsilon_3 \sim N(\mu,\sigma)$. Here, λ has a lognormal distribution, and thus λJ is always positive and λ is skewed

$$W = \lambda J = e^{\varepsilon_3} J \qquad [3]$$

$$E(\lambda) = e^{\mu + 0.5\sigma^2} \qquad [4]$$

upward. In this specification:

$$VAR(\lambda) = e^{2\mu+\sigma^2}(e^{\sigma^2}-1) \qquad [5]$$

Taking logarithms on both sides of [3], we have

$$\ln W = \ln J + \varepsilon_3 \qquad [6]$$

$$\ln W = \ln J + \mu + \varepsilon_4 \qquad [7]$$

where $\varepsilon_4 \sim N(0,\sigma)$. As with the earlier, less realistic model, the parameters can be estimated using maximum likelihood. A simple extension is to let $\mu = \beta_0 + \beta_1 J/100$. The "100" is just a scale factor that has no effect on analysis. This specification allows frequent smokers to smoke larger or smaller joints than average smokers.

The most important estimate is $E(\lambda)$, the average weight of a marijuana cigarette. An estimate of W, then, is:

$$\hat{W} = E(\lambda)J$$

This tells us that if a respondent says he smoked J joints during the month (TOTAL JOINTS), then $E(\lambda)J$ is the best estimate of the quantity (in ounces) of marijuana smoked.

Table A4-1 presents parameter estimates based on an analysis of 1623 smokers who reported DAYS, JOINTS, and AMOUNT. Before estimating these parameters, the analysts changed some of the data.

TABLE A4-1

Regressions Results: The Total Amount of Marijuana Smoked in the Past Month

Parameter	Parameter Estimate	Standard Error	Probability
β_0	-4.95	0.24	.0000
β_1	0.13	0.11	.0000
α_2	1.50	0.39	.0001
σ	1.08	0.013	.0000

Source: NHSDA 1991

Before calculating TOTAL JOINTS, responses of more than 30 for JOINTS (number of marijuana cigarettes smoked per day in the past month) were truncated to 30. These extreme responses represented only about 0.1% of the total number of monthly users.

After calculating TOTAL JOINTS, analysts compared TOTAL JOINTS with AMOUNT and corrected for extreme inconsistencies between (or highly unlikely combinations of) the two variables. If JOINTS >= 100 and AMOUNT <= 20 joints or if JOINTS >= 200 and AMOUNT <= 2 ounces, then analysts assumed that the respondents had mistakenly given the total number of joints they had smoked in the past month for the question on JOINTS (number of marijuana cigarettes smoked per day in the past month). For these respondents, analysts treated JOINTS as TOTAL JOINTS in calculating the quantity estimates.

Results from the analysis imply that a person who smokes 1 joint per month uses 0.013 ounces (0.37 grams per joint) of marijuana. A person who smokes thirty joints per month uses 0.4 ounces (0.38 grams per joint) of marijuana. A person who smokes 120 joints per month uses 1.79 ounces (0.43 grams per joint) of marijuana. Applying the parameter estimates from Table A4-1, Equation [7] was then used to compute the average weight per joint (W/J) for every respondent in each year of the NHSDA. Results, which appear in Table 6 of the main report, are used in the calculations reported in the body of this report.

Imputing Joints

A related problem is that the variable JOINTS was sometimes missing. We could not just substitute the average response when JOINTS were known, because those with missing data seemed to have different usage patterns from those who did not have missing data. Instead, we estimated regressions where JOINTS was the dependent variable and MJFREQ was the independent variable. MJFREQ is "frequency used marijuana in the past 12 months." We used results from these regressions to impute responses when JOINTS was missing.

MJFREQ is coded:

1 -- several times a day;
2 -- daily;
3 -- almost daily (3 to 6 days a week);
4 -- 1 or 2 times a week;
5 -- several times a month (about 25 to 51 days a year);
6 -- 1 or 2 times a month (12 to 24 days a year);
7 -- every other month or so (6 to 11 days a year);
8 -- 3 to 5 days in the past 12 months;
9 -- 1 or 2 days in the past 12 months.

We treated this variable as a continuous measure. To capture nonlinearities, we added an additional independent variable $MJFREQ^2 = MJFREQ \cdot MJFREQ$.

The regression had two special features. The first was that the respondent could have said that he used zero joints during the month before the interview. After all, marijuana use during the year (MJFREQ) does not imply marijuana use during the month before the survey (JOINTS). To take this special feature into account, the regression specification was written:

$$Z = \alpha_0 + \alpha_1 MJFREQ + \alpha_2 MJFREQ^2 + \varepsilon$$

$$JOINTS = Z \text{ when } Z \geq 0$$

$$JOINTS = 0 \text{ otherwise}$$

where

$$\varepsilon \sim N(0,\sigma)$$

$$\sigma = \beta_0 + \beta_1 Z$$

Note that in this specification the error term is heteroscedastic and a linear function of the underlying latent variable Z.

Table A4-2 shows regression results.

TABLE A4-2

Regression Results: The Average Number of Joints Smoked in the Past Month

	Model 1		Model 2	
Parameter	Parameter Estimate	Probability	Parameter Estimate	Probability
α_0	81.23	0.00	12.62	0.09
α_1	-20.64	0.00	-1.42	0.24
α_2	1.30	0.00	-0.07	0.30
β_0	12.15	0.00	20.30	0.00
β_1	0.48	0.00	2.18	0.05
N	1418		190	

Source: NHSDA 1991

The table shows two regressions. Model 1 was estimated for the 1418 respondents who reported use of marijuana in the 1991 NHSDA survey. Model 2 was estimated for the 190 respondents whose use of marijuana was imputed by SAMHSA. We estimated two separate models because specification testing showed that estimates based on the 1,418 cases did not work well for the 190 cases and vice versa.

The regressions overpredict slightly. Based on the 1,418 cases, the regressions predict 23.4 joints on average per month. In reality, respondents said they used an average of 21.6 joints per month. For the 190 cases, the prediction was 10.7 joints on average per month and the actual was 8.5 joints. Because these predictions were only used when responses were missing for the variable JOINTS, we considered them to be close enough for our purposes.