Drug Availability Estimates in the United States

2012

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Foreword

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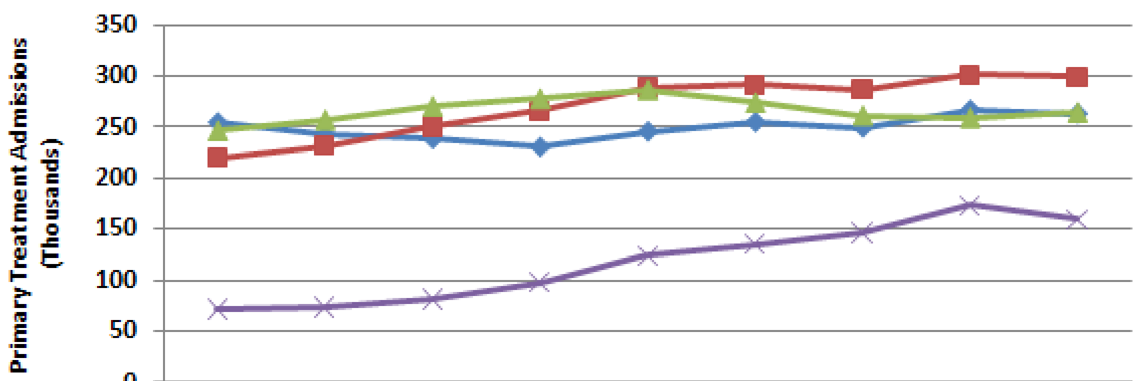
The Office of National Drug Control Policy sponsored research to update previously published estimates of illegal drug availability on the streets of the United States based on both demand and supply data indicators. The demand-based methodology, published as What America's Users Spend on Illegal Drugs (WAUSID), estimates the magnitude of drugs in the United States by calculating consumption based on surveys of drug use prevalence and frequency. The supply-based methodology, published as Drug Availability Estimates in the United States (DAEUS), estimates the magnitude of drugs in the United States based on supply indicators such as potential production estimates and seizures. This foreword integrates results of these updates.

Trends in the demand and supply-based availability should correlate to trends in the drug consequences (e.g., drug poisonings, drug treatment) in the United States. Figure FW.1 shows the number of reported primary drug treatment admissions for cocaine, heroin, marijuana, and stimulants (which includes methamphetamine) from 1998 through 2006. Cocaine admissions reached a low in 2001, then rose slightly to 263,000 in 2006. Heroin admissions peaked in 2002, then fell slightly in 2006. Marijuana admissions rose steadily from 1998 to 2002, then plateaued through 2006. Treatment admissions for stimulants rose from 1998, until peaking in 2005, then dropped slightly in 2006. Where differences occur between trends in the availability estimates and consequences, potential explanations will be discussed. Based on this evidence, expectations are that methamphetamine availability and use increased over most of 2001 through 2006. For the other drugs, availability and use were relatively constant, although cocaine use may have increased and heroin use may have decreased. Expected changes are not large.

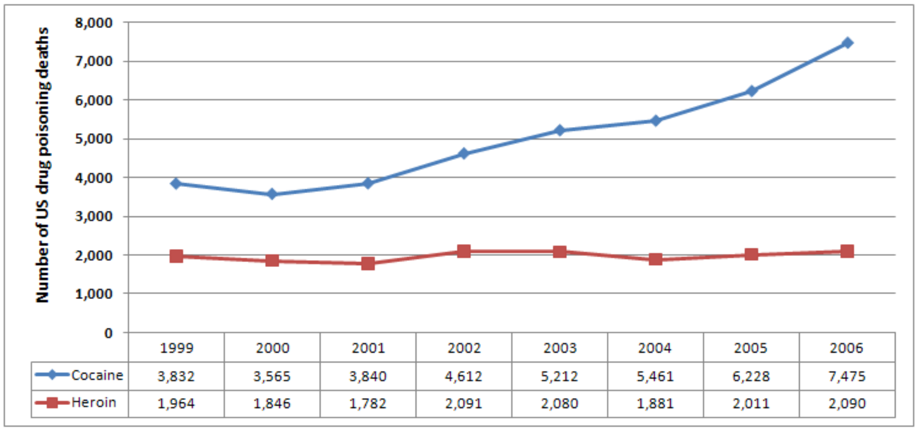
Figure FW.1: Trends in Primary Drug Treatment Admissions in the United States: 1998–2006 (TEDS)



	1998	1999	2000	2001	2002	2003	2004	2005	2006
Cocaine	254	242	239	231	246	255	249	266	263
Marijuana	220	232	251	266	289	292	287	301	300
Heroin	247	258	270	278	286	274	262	259	265
Stimulants	71	74	81	98	124	135	147	173	160

Figure FW. 2 shows the trends in drug poisoning deaths for cocaine and heroin. Heroin deaths were flat at about 2,000 annually from 1999 through 2006. Annual cocaine poisoning deaths averaged 3,750 from 1999 to 2001, then rose annually to over 7,000 by 2006. Again, the implication is that heroin's availability and use has been stable, but cocaine's availability and use appears to have increased.

Figure FW.2: Trends in Number of Poisoning Deaths Involving Cocaine or Heroin in the United States: 1999–2006 (NCHS)



The demand and supply-based availability estimates should be equivalent, assuming that the amount of drugs supplied to U.S. streets each year is all consumed, with no net accumulation. However, it is unlikely that demand-based and supply-based estimates will be equivalent given the complexities and uncertainties of the covert activities of producing, distributing, and consuming illegal drugs. Accurate measurement of drug use is a challenge to surveys seeking valid and reliable information on drug use frequency and expenditures for drug purchase. Resource limitations result in gaps in data collection: for example, the Arrestee Drug Abuse Monitoring (ADAM) project, a key data source on chronic drug use, had no data collection from 2004 through 2006. On the supply side, remote sensing of illicit drug cultivation is challenged by dispersed and hidden crops, and adaptations to aerial and manual eradication techniques. Given the dearth of information regarding the quantity of chemicals traded on the black market or diverted to synthetic drug manufacture, quantifying the amount of illegal synthetics produced each year is a challenge. Furthermore, all of these indicators have a temporal component that is difficult to gauge. For example, drugs departing source areas may be delayed in shipment due to consolidation, changes between conveyances, and delays in delivery to avoid law enforcement suspicion. Therefore, the models often depend on averages or assumptions that add to the uncertainty of the estimates.

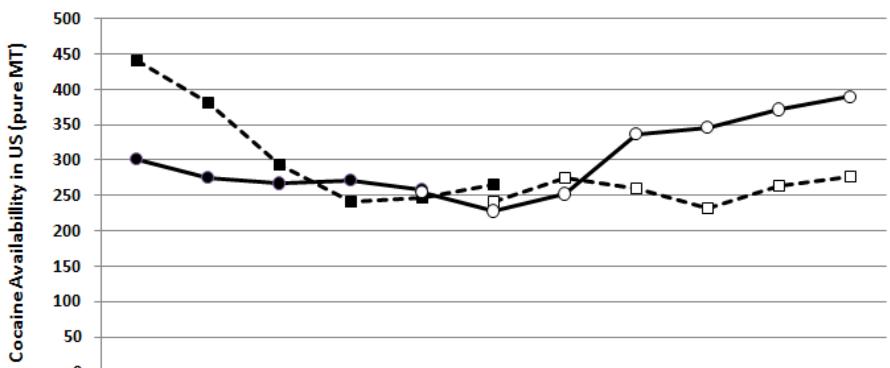
These challenges are worth confronting because estimates are of benefit to decision-makers in putting various indicators, counter-drug program performance data, and trends in perspective. For example, the value of a reduction of 10 metric tons of a drug depends on whether the total street availability is 100 or 1,000 metric tons. The estimated trends are also useful as a general indicator of whether the problem is getting better or worse. Although the current estimates only extend through calendar year 2006, they provide a more mature baseline for follow-on estimates (i.e., the most recent prior estimates extend only through 2000–2001).

Cocaine

Annual cocaine consumption was determined by estimating the number of occasional and chronic users, multiplying their estimated numbers by their average weekly expenditures for cocaine, and then converting total expenditures to a pure amount by dividing by the price per pure gram of cocaine. The consumption figures from WAUSID (2000 to 2006) connect seamlessly with the previously published estimates (see Figure FW.1).

The supply-based cocaine availability estimates covered by DAEUS (2001-2006) also connect smoothly with the previously published supply-based availability estimates. These were calculated by beginning with the cocaine potential production estimate (calculated separately each year by UN and U.S. analysts), subtracting seizures, then assuming a market split between the United States and the rest of the world. The remainder, after subtracting the rest-of-the-world consumption, is what is available for consumption in the United States. Figure FW.3 shows that the demand and supply-based cocaine availability estimates remained at 250 to 275 pure metric tons until 2003, when they diverged: the demand-based estimates rose in subsequent years, while the supply-based availability estimates remained fairly steady. The rise in the demand-based estimates does correlate to the rise in cocaine poisoning deaths shown in Figure FW.2, but other indicators will also be considered.

Figure FW.3: Trends in the Estimated Availability of Cocaine in the United States: 1996-2006



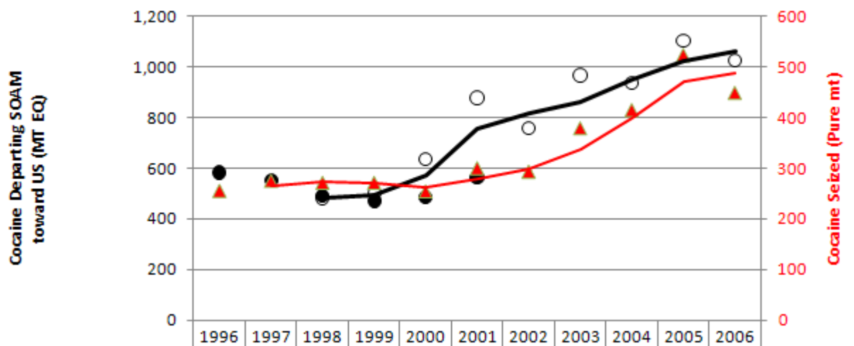
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
DAEUS 2002 (table 1-1)	441	380	294	242	246	266					
Supply-method						241	275	260	231	264	277
WAUSID 2001 (table 2)	301	275	267	271	259						
Consumption					254.6	228	252.5	336.6	346.2	371.7	389.6

Observed movements of cocaine and seizures are other indicators of cocaine availability that can be compared with the demand and supply-based estimates of availability. The Consolidated Counterdrug Data Base (CCDB) tabulates observed (through detection or intelligence) cocaine load movement departing South America. Figure FW.4 compares these CCDB amounts with the corresponding amounts calculated by the previously published DAEUS,[1] and shows an increase in the amount of cocaine departing South America toward the United States after 2001. The amount of cocaine seized worldwide (shown in red in Figure FW.3) rose after 2003. With stable law enforcement resources, increasing

[1] These corresponding values are calculated by assuming that 2/3 of cocaine departing South America (line 7 in Table 1-1 of the DAEUS, 2002) heads toward U.S. markets. The 2/3 figure was used by the Interagency Assessment of Cocaine Movement (IACM) between 2002 and 2007.

seizures could be a surrogate measure of flow. Thus, the cocaine movements from South America and the seizure data both point to increasing cocaine supply from 2003 to 2006.

Figure FW.4: Comparison of Trends in Cocaine Flow toward the United States and Seizures: 1996-2006



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
○ CCDB			483	501	637	878	760	968	939	1,104	1,025
● DAEUS 2002	583	552	492	471	486	562					
▲ World-wide seizures	256	276	272	272	255	301	294	380	416	525	450

To understand these divergent trends between availability estimates, an understanding of the events during 2000 to 2003 is important. Two significant operations occurred during this period affecting the amount of cocaine departing South America: Plan Colombia and Operation Purple. Plan Colombia was developed as a six-year plan to end Colombia's internal conflict, eliminate drug trafficking, and promote economic and social development. U.S. assistance to Plan Colombia from FY 2000 through FY 2005 included expansion of coca spray operations. Operation Purple was a voluntary initiative launched in 1999 to track shipments over 100 kilograms of the key cocaine precursor chemical potassium permanganate to reduce its use in cocaine potential production. Both of these programs reduced cocaine potential production in Colombia below levels that would otherwise have been observed from 2000 to 2003.

Plan Colombia increased coca spraying 160 percent from 2000 to 2003, as shown in Figure FW.5. Coca spraying disrupted the equilibrium of both coca harvesting by farmers and the process for estimating coca cultivation and cocaine potential production. This rapid rise in spraying caused a farmer response of replacing their sprayed coca crops: seedbeds were readied for replanting, cultivated areas were expanded outside traditional areas, new plantings increased with smaller fields, and crop concealment increased through plantings under canopy or among licit cultivation. Fortunately, cultivation and field productivity decreased in sprayed areas, but unfortunately, farmer adaptation to hide crops may have caused surveys to understate the actual amount of production. Operation Purple was the other significant activity over the 2000–2003 timeframe that affected Colombian cocaine. That 1999 operation restricted the availability in Colombia of potassium permanganate, which is used for oxidation during the production of cocaine. Potassium permanganate reacts (oxidizes) with yellowish-brown colored impurities in coca paste, which then precipitate out of solution. Highly oxidized cocaine is very white and fluffy. Failure to remove these impurities results in a final product (i.e., cocaine hydrochloride) of poorer quality with respect to cocaine content and especially color and appearance (Casale & Klein, 1993).

Figure FW.5: Area Sprayed in Colombia: 1996-2006 (Thousands of Hectares)

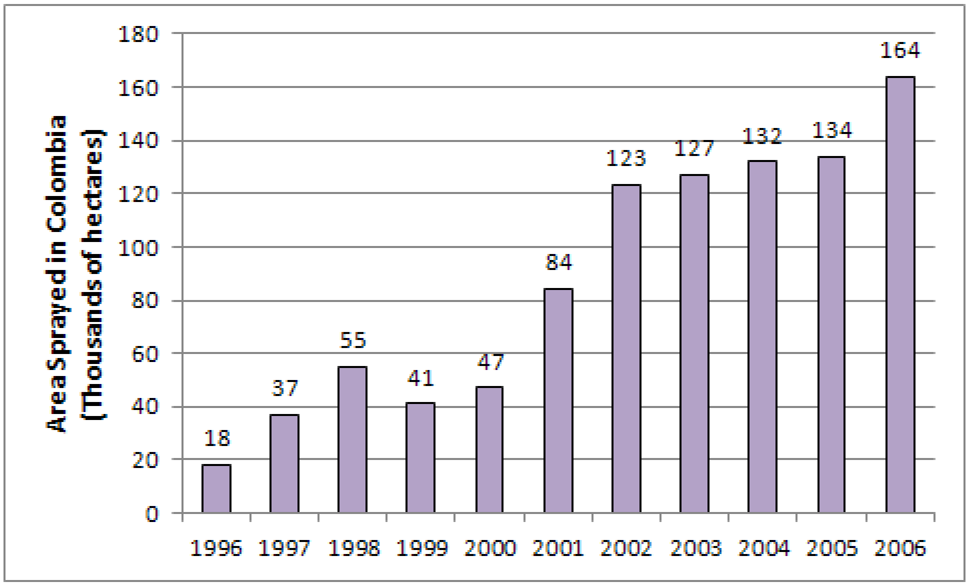
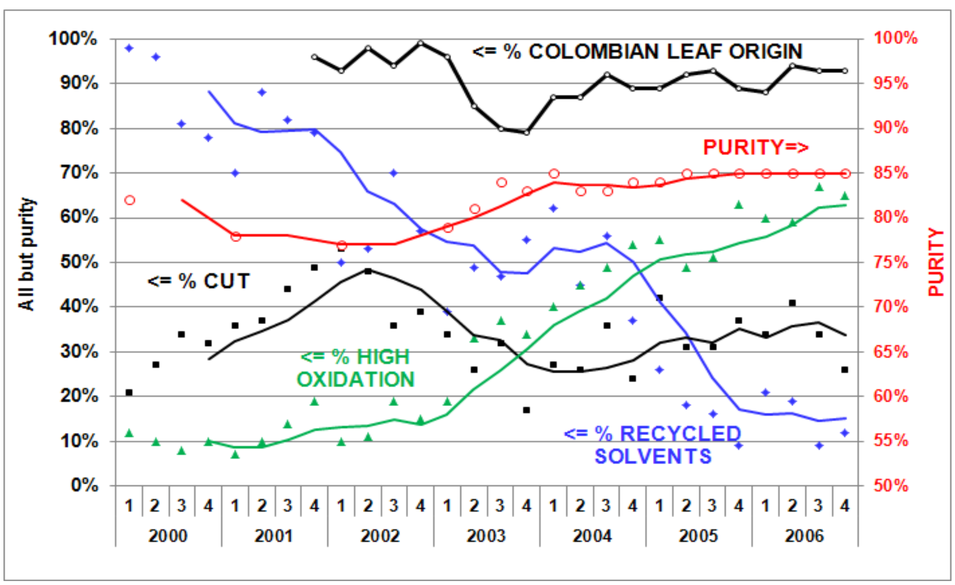


Figure FW.6 shows that from 2000 through 2003, less than 20 percent of the cocaine seizure specimens analyzed by DEA's Special Testing Laboratory were highly oxidized. Lower oxidation results in a dark, lumpy and less attractive product. Purity during that period dropped as the less oxidized cocaine was cut, predominately with white crystalline chemicals (caffeine and lactose). At the time, DEA linked the decline in purity to the restriction of potassium permanganate used for oxidation.[2] By 2003, the effects of Operation Purple dissipated as shown in Figure FW.6: the fraction of highly oxidized specimens began increasing, the fraction of cut specimens declined, and purity rose.

Figure FW.6: Forensic Trends in Large Cocaine Seizures (>10kg): 2000-2006



2 Declining Cocaine Purity Levels Are a Step in the Right Direction, DEA website, http://www.justice.gov/dea/ongoing/cokepurity.html

This rise in purity had a dramatic impact on the calculated demand-based availability, which is computed by dividing total expenditures by price per pure gram. Total expenditures were flat from 2000 to 2006 ($35B to $40B), so as purity rose from 2003 to 2006, the price per pure gram declined ($136/pure gram in 2000 to $97/pure gram in 2006), resulting in a rise in the estimated availability of pure cocaine.

Over the period covered by this report, 2000 to 2006, the number of cocaine users and their expenditures were stable, thus leading to an expectation of a stable consumption estimate. However, the demand-based measure of availability was calculated to be rising. This was because the demand-based estimate of availability is a measure of pure cocaine consumed. It appears that the bulk volume consumed was stable, but the pure volume rose as less of the product was cut.

In summary, the cocaine availability estimates calculated for this latest update connect smoothly with the previously published estimates, and are fairly stable at 240–275 pure metric tons over the period 2000 through 2003. Disruption of coca cultivation and cocaine production by the Colombian government affected the availability estimates from 2003 through 2006. The purity rise resulted in a calculated rise in the demand-based estimate of cocaine availability in the United States. Supply-based availability estimates remained steady, but were subject to much uncertainty due to increased difficulty in estimating coca cultivation when spray activities increased.

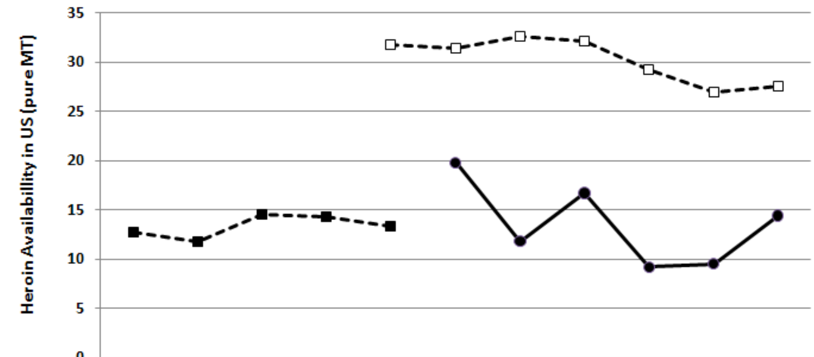
Heroin

The demand and supply-based methodologies for measuring heroin availability were similar to those used for cocaine. Demand-based availability was calculated by multiplying the number of heroin users by their annual expenditures, then dividing by the unit retail price of pure heroin. Supply-based availability estimates were calculated by beginning with potential production from foreign sources, then subtracting seizure losses.

Forensic signature analyses of heroin purchases and seizures in the United States indicated that the majority of heroin consumed in the United States comes from source areas in South America (primarily Colombia) and Mexico. From 2001 to 2006, Mexican heroin potential production was fairly level, averaging 10 pure metric tons, while Colombian heroin potential production averaged 10 pure metric tons annually in 2000–2001, but dropped to half that by the middle of the decade. After reducing the potential production amount by seizures, the supply availability estimates in the United States showed a declining trend of 10–20 pure metric tons of heroin, as shown in Figure FW.7.

Colombian heroin potential production has been difficult to consistently estimate. Because of the difficulty in obtaining clear imagery in the “cloud forest” where Colombia’s poppy crop grows, the estimate generally has greater uncertainty than other cultivation estimates (CNC, 2003). Persistent cloud cover in 2000 and 2005 prevented the completion of cultivation surveys. Backcasting adjustments to prior potential production estimates, based on updated yield surveys, were made. For example, the Colombian potential heroin production estimate in 2001 was 4.3 pure metric tons. The 2001 estimate was adjusted to 15.1 pure metric tons two years later, then to 11.4 pure metric tons by August 2006.

Figure FW.7: Trends in the Estimated Availability of Heroin in the United States: 1996-2006



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
WAUSID 2001 (table 2)	12.8	11.8	14.5	14.3	13.3						
Consumption					31.8	31.4	32.6	32.1	29.2	26.9	27.6
Supply-method						19.8	11.8	16.7	9.2	9.5	14.4

The methodology for calculating the demand-based availability estimate (consumption) was similar to that for cocaine. Total expenditures (about $12B) were divided by the average price per pure gram of heroin (about $400 per pure gram) to yield approximately 30 pure metric tons of heroin. Figure FW.7 shows the results and shows a slightly declining trend. In comparison with the previously published WAUSID, expenditures were stable and equivalent. However, the average purchase price per gram in 2000 was adjusted from $839 per pure gram (in WAUSID, 2001) to $461 per pure gram. This caused a doubling of the heroin consumption estimate.

The heroin price estimated for 2000 changed from the earlier version of WAUSID to this current version. There are two reasons. Prices have always been based on a statistical model that was estimated using data from the System to Retrieve Drug Evidence (STRIDE). However, using that statistical model to predict retail prices requires knowledge of the distribution of expenditures per purchase (e.g., 20 percent of purchases were for $20, 50 percent were for $40, etc.). This distribution was unknown when the earlier version of WAUSID was prepared and had to be estimated from crude data. The ADAM survey provided the distribution for this current version of WAUSID. The second reason is that STRIDE data were unavailable for 2000 when preparing the earlier version of WAUSID. Therefore the price reported for 2000 was a projection that, in retrospect, was too high.

When the improved price estimates are taken into account, estimates of heroin use from the earlier version of WAUSID are broadly consistent with estimates from this current version. The discrepancy between the demand-based and supply-based estimates is disconcerting, but the report argues that the differences are not large if Colombian poppy cultivation is understated because of cloud cover.

Methamphetamine

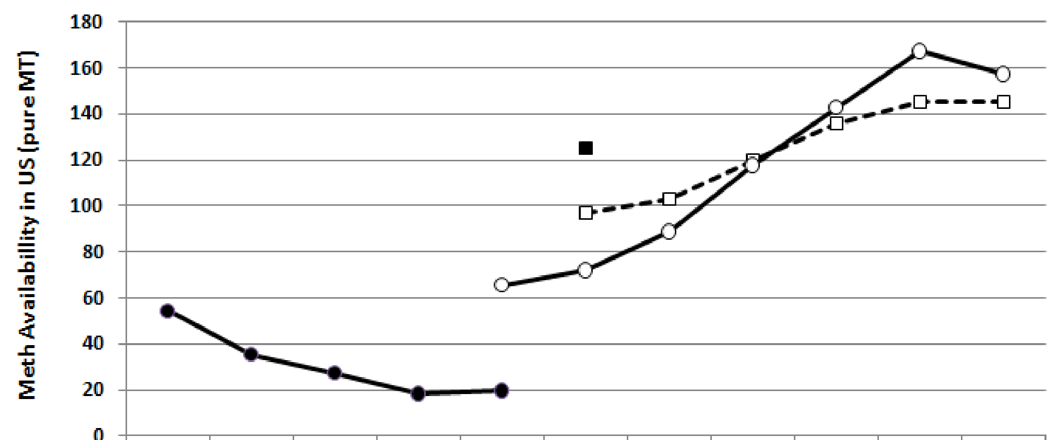
The demand-based methodology for measuring methamphetamine availability was similar to that used for cocaine. Demand-based availability (consumption) was calculated by multiplying the number of meth users by their annual expenditures, then dividing by the unit retail price of pure meth. The results, shown in Figure FW.8, show an estimated meth consumption of 66 pure metric tons in 2000, peaking at

165 pure metric tons in 2005. The previously published WAUSID estimated meth consumption as 20 pure metric tons in 2000.

The large difference in the meth consumption estimate between this WAUSID version and the prior version was due to improved information from the ADAM survey. As explained for heroin, ADAM provided knowledge of the distribution of expenditures per purchase, which was input to a statistical model that predicted retail prices. ADAM also provided improved data for estimating the number of chronic meth users and their expenditures.

The data and methodologies for calculating the supply-based estimates of methamphetamine availability improved substantially since the last published WAUSID in 2001. Information on meth lab seizure incidents, black market pseudoephedrine, and Southwest Border meth seizures was combined to develop supply-based meth estimates that were close to the consumption estimates. Figure FW.8 shows the close correlation.

Figure FW.8: Trends in the Estimated Availability of Methamphetamine in the United States: 1996-2006



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
DAEUS 2002 (table 1-1)						125					
Supply-method						96.6	102.6	119.9	135.9	145.1	144.9
WAUSID 2001 (table 2)	54	35	27	18	20						
Consumption					66	72	89	118	143	167	157

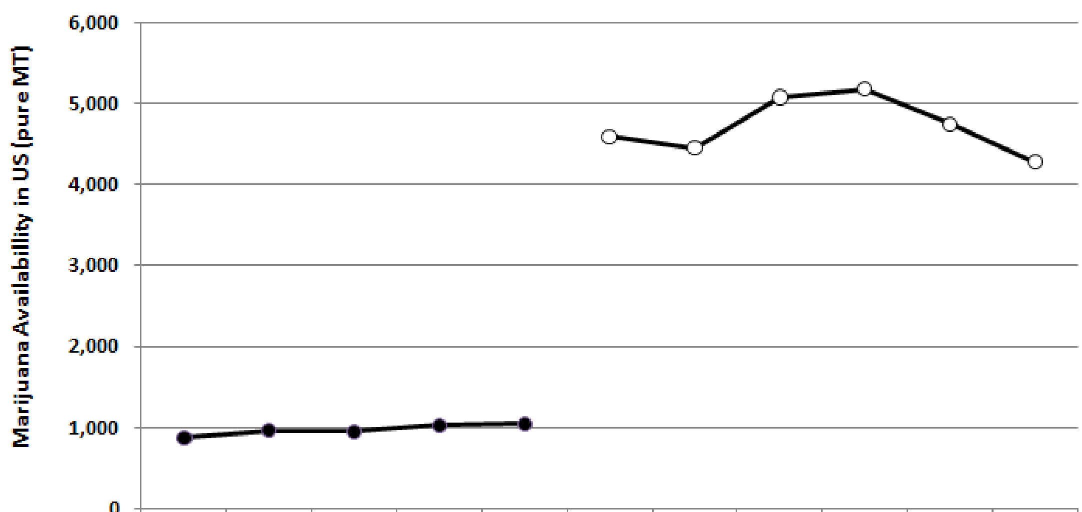
Marijuana

The calculations for marijuana users and expenditures were based exclusively on the National Survey on Drug Use and Health (NSDUH) data. Separate estimates were computed for chronic users (4+ days of use in the last month) and occasional users (1–3 days of use in the last month). The amount of marijuana use reported in this version of WAUSID is much larger than the amount of marijuana use reported in the previous version of WAUSID. Prior to 2000, estimation was based on a combination of Drug Use Forecasting (DUF) data, the National Household Survey on Drug Abuse (NHSDA), and the Monitoring the Future Survey. None of these surveys asked questions about expenditures on marijuana; DUF provided uncertain coverage of marijuana use; and there were no credible adjustment factors for underreporting in the NHSDA. This changed in 2000 when the Arrestee Drug Abuse Monitoring (ADAM) survey, which provided a battery of market questions, replaced DUF. It changed again in 2001 when the NSDUH, which asks a series of questions about marijuana market behavior, replaced the NHSDA. Current estimates are based on the NSDUH starting in 2001; complementary estimates come from ADAM for 2000 through 2003.

Figure FW.9 shows the estimates for marijuana consumption over the period 2001 to 2006 have been between 4,200 and 5,200 metric tons. Marijuana supply estimates are more difficult to calculate due to the uncertainty in marijuana yield, both domestically and from foreign sources. The National Drug Intelligence Center (2010) has concluded:

> No reliable estimates are available regarding the amount of domestically cultivated or processed marijuana. The amount of marijuana available in the United States—including marijuana produced both domestically and internationally—is unknown. Moreover estimates as to the extent of domestic cannabis cultivation are not feasible because of significant variability in or nonexistence of data regarding the number of cannabis plants not eradicated during eradication seasons, cannabis eradication effectiveness, and plant yield estimates. (Note 16, p. 36.)

Figure FW.9: Trends in the Estimated Availability of Marijuana in the United States: 1996-2006



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
WAUSID 2001 (table 2)	874	960	952	1,028	1,047						
Consumption						4,595	4,453	5,082	5,182	4,750	4,285

Executive Summary

This version of *Drug Availability Estimates in the United States (DAEUS)* provides supply-based estimates for four major illegal drugs (cocaine, heroin, marijuana, and methamphetamine) in the United States. Availability measures are important to policy formation, execution, and monitoring. Reliable estimates have been difficult to develop because of the clandestine nature of drug production and trafficking. Nevertheless, the last decade has produced credible approaches, and, building on those emerging methodologies, an interagency team assembled by the Office of National Drug Control Policy issued a consensus statement identifying the best approaches for estimating the 2001 supply of drugs to the United States (Drug Availability Steering Committee, 2002). The methodology has since evolved, in part because the original methodology was inadequate, producing estimates that contradict other evidence about levels and trends in drug use in the United States.[3]

As a result of this evolution of the methodology, this report uses an economic model of supply and demand to structure estimation and interpretation of the amount of drugs available in the United States. The methodology argues that the data are inadequate to reach conclusions about year-to-year variation in the availability of illegal drugs to the United States and that a more useful perspective is to focus attention on long-term changes in drug availability. Long-term trends can be estimated with much greater precision than can short-term changes.

As discussed in the body of this report, the estimation approach varies by drug due to the nature of the drug (e.g., cocaine and heroin are produced solely in foreign countries, whereas methamphetamine and marijuana have both a foreign and domestic production component) and the availability of data (e.g., data about cocaine and heroin begin with estimates of hectares of coca and poppy cultivation, while there is no such counterpart for marijuana and methamphetamine). Finally, the report argues that there are no credible supply-based estimates for marijuana.

Why are Availability Estimates Important?

The 2010 *National Drug Control Strategy* calls for action along the entire spectrum of prevention, early intervention, treatment, recovery, criminal justice, domestic law enforcement, and international cooperation. Cooperation on illicit crop reduction, drug interdiction, and law enforcement operations are important components of the *Strategy*'s approach to international partnerships:

> The production, trafficking, and consumption of drugs undermine governments and social institutions and impair licit economic development, democratization, and the rule of law in our partner nations. Therefore, the United States cooperates with the international community to disrupt the global drug trade through interdiction, anti-trafficking initiatives, drug crop reduction, intelligence sharing and partner nation capacity building. These programs, which have proven effective in the past, must be updated to reflect a changing world. (p. 77)

[3] See *Chapter 1: Introduction to the Methodology* for a discussion.

The overarching question is this: How can a policy maker *tell* that a program has been effective? Availability estimates can be helpful in two ways.

First, availability estimates provide a measure of scale. Suppose that interdiction authorities seize or otherwise destroy 100 metric tons of cocaine. This level of seizure might be seen as highly significant if total availability is near 300 metric tons but not very important if total availability is near 3,000 metric tons. Credible measures of scale are important for assessing successful anti-drug programs.

Second, availability estimates provide a measure of trends. Of course, successful policy may simply maintain equilibrium where the supply of drugs is maintained at a lower level than would be true absent the policy. There may be no trend. Still, the *National Drug Control Strategy* (2010, p. 86) sets quantitative goals for reducing availability. Credible trend estimates are required to effectively measure progress against the stated goals.

Thoughtful critics have complained about both the inadequacy and irrelevance of availability estimates (Reuter, 1996; Reuter & Greenfield, 2001; Thoumi, 2005). Their criticism is understandable. Availability is estimated with considerable imprecision, and one might question whether an estimate for any given year is sufficiently accurate to be a useful gauge for evaluating public policy. This report expresses its authors' opinions that estimates have sufficient inaccuracy that using them to judge year-to-year changes is impractical. The authors are more optimistic about using the estimates to judge long-term trends, and the authors encourage readers to use the estimates in that capacity. This report provides estimates of uncertainty for trends, so readers can judge whether trend estimates have sufficient validity to be judged as useful.

Estimates: A Summary

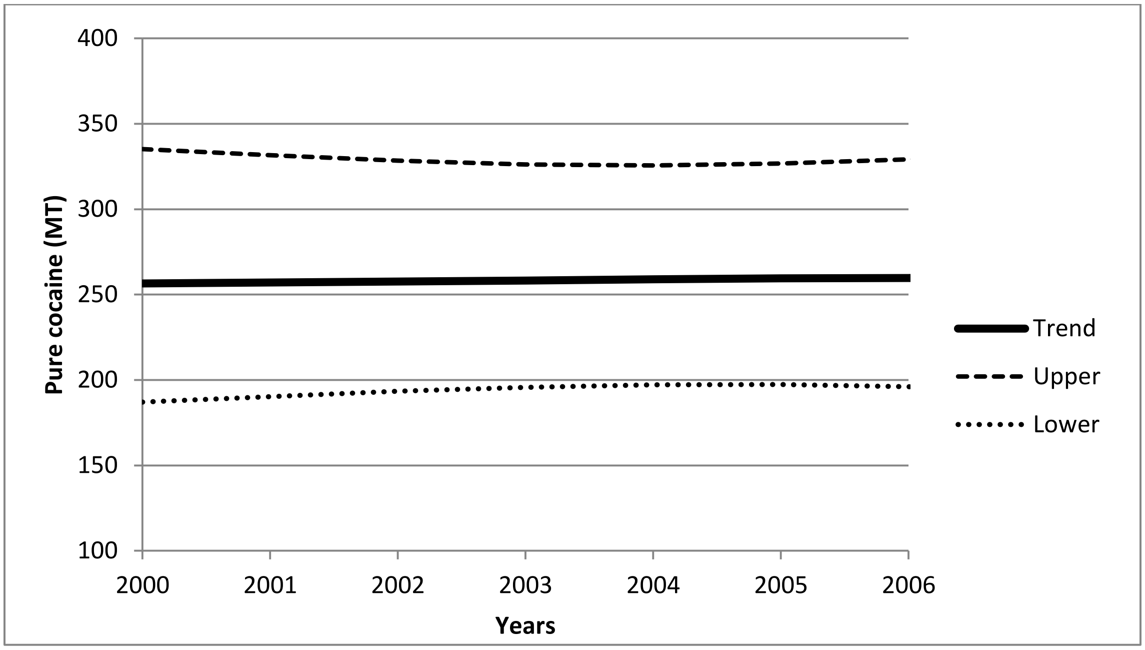
The following summarizes the methodology and estimates for cocaine, heroin, methamphetamine, and marijuana, respectively.

Cocaine

The estimation of the availability of cocaine in the United States entails three consecutive steps. First, worldwide *pure cocaine potential production* after coca eradication is estimated using data provided by the Crime and Narcotics Center (CNC), the Drug Enforcement Administration (DEA), and the United Nations Office on Drugs and Crime (UNODC). Long-term trends are then judged using the CNC and UNODC estimates. Results suggest that the potential production of cocaine has been fairly constant at about 885 metric tons per year during the period of interest. *Seizures* are then subtracted from pure cocaine potential production to get an estimate of net cocaine potential availability. The United Nations Office of Drugs and Crime (UNODC) estimates that about 42 percent of cocaine is seized each year before it reaches domestic and foreign markets, leading to the long-term trend estimate that about 518 metric tons of cocaine is available for worldwide consumption each year. Finally, the estimated net cocaine potential production is *proportioned between that destined for the United States and that destined for the rest of the world*.

The resultant trend estimates suggest that Americans used somewhat more than 250 metric tons per year of pure cocaine during the last decade, but there is a broad confidence interval around this estimate (see Figure ES.1 below). The low bound is slightly less than 200 metric tons; the high bound is between 300 and 350 metric tons.

Figure ES.1. Trends in U.S. Cocaine Availability (Metric Tons)



While the figure implies that U.S. availability has remained fairly constant, the estimates may not pay sufficient attention to evidence that U.S. consumption has varied relative to consumption in the rest of the world (not illustrated in the figure). Unfortunately, consumption estimates outside the United States are highly uncertain, so making suitable adjustments is challenging.

As noted, the methodology leading to Figure ES.1 has evolved. The Drug Availability Steering Committee (2002, p. xi) provided a consensus statement identifying the best approaches for estimating the 2001 supply of drugs to the United States:

> This estimate of 260–270 pure metric tons was determined through the integration of many routinely reported sources such as the potential cocaine production estimates reported annually by the Central Intelligence Agency, the Office of National Drug Control Policy's (ONDCP) annual consumption estimates, and worldwide seizure statistics.... The greatest uncertainty in the estimate is the amount of cocaine consumed by foreign markets due to a lack of routinely collected standardized data.

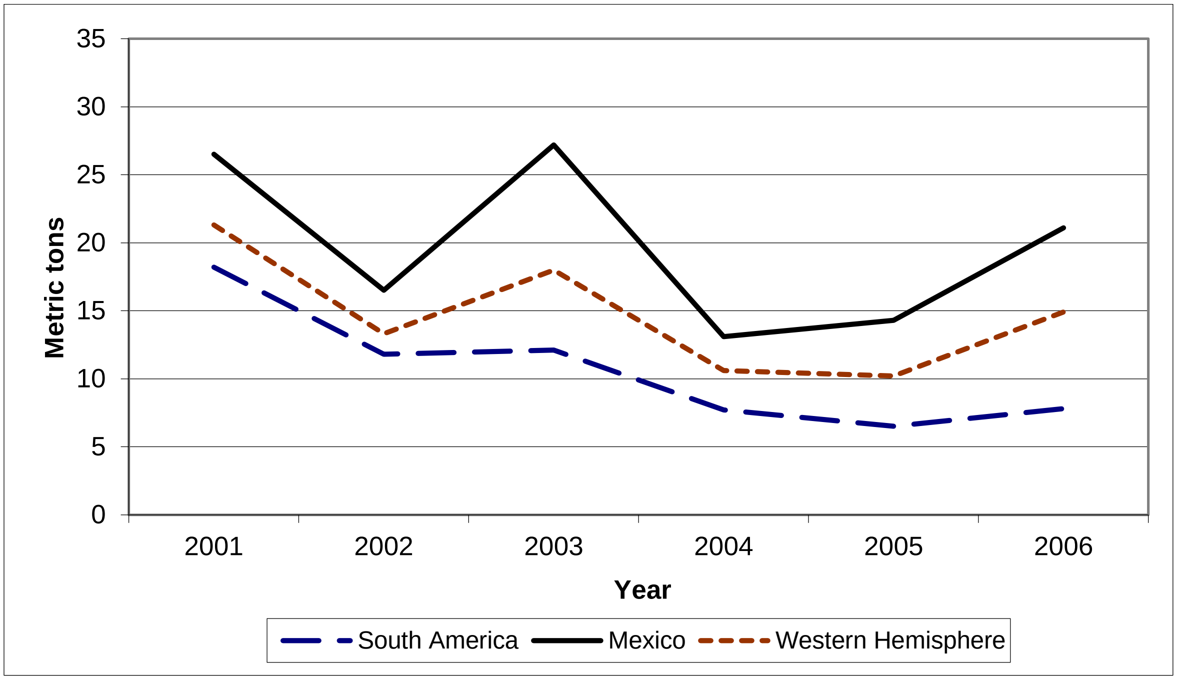
This consensus estimate (260–270 metric tons for 2001) is consistent with the estimate reported in Figure ES.1. However, this current report shows that the consensus estimation methodology leads to highly variable estimates post 2001.

Heroin

Heroin availability in the United States is estimated in two steps. First, Western Hemisphere (i.e., Colombia and Mexico) availability is estimated by subtracting source country consumption and total losses from the quantity of heroin produced.[4] Second, once the availability of heroin from the Western Hemisphere is calculated, estimates of total heroin available to the United States are scaled up to account for heroin that originates outside the Western Hemisphere, i.e., heroin from Southeast and Southwest Asia.[5]

Figure ES.2 presents estimates and long-term trends. For the period considered here trends have been fairly flat.

Figure ES.2. Three Estimates of Heroin Availability in the United States (Metric Tons)



The Steering Committee (2002, p. xi) characterized its consensus methodology as pending. It reported:

> This estimate of 13–18 pure metric tons was based on the number of users, their frequency of use and expenditures, and the retail price of heroin. There is uncertainty in the estimate due to the widely varying prices of heroin and user behavior. A supply-based estimate could not be determined due to inconsistency between the current Colombia potential production estimate and the Heroin Signature Program's estimate of South American heroin entering the U.S domestic market. The apparent discrepancy requires the development of a follow-on process to develop a rational estimate.

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4 Estimates of potential heroin production were provided by CNC. These estimates are based on satellite photos of the area under opium poppy cultivation in each year. A series of production and processing parameters are used to estimate the total amount of heroin that could be produced from these fields.

5 The methodology relies upon potential production estimates only from the Western Hemisphere since most heroin produced in Mexico and South America (primarily Colombia) is destined for the U.S. and almost none of the heroin produced outside the Western Hemisphere (i.e., Southwest and Southeast Asia) is destined for the U.S.

The Steering Committee's pending methodology led to 2001 estimates that are broadly consistent with the estimates reported in this version of DAEUS. However, the Steering Committee methodology and the methodology used in DAEUS are very different. The Steering Committee provided oversight during the development of the new methodology explained in this report.

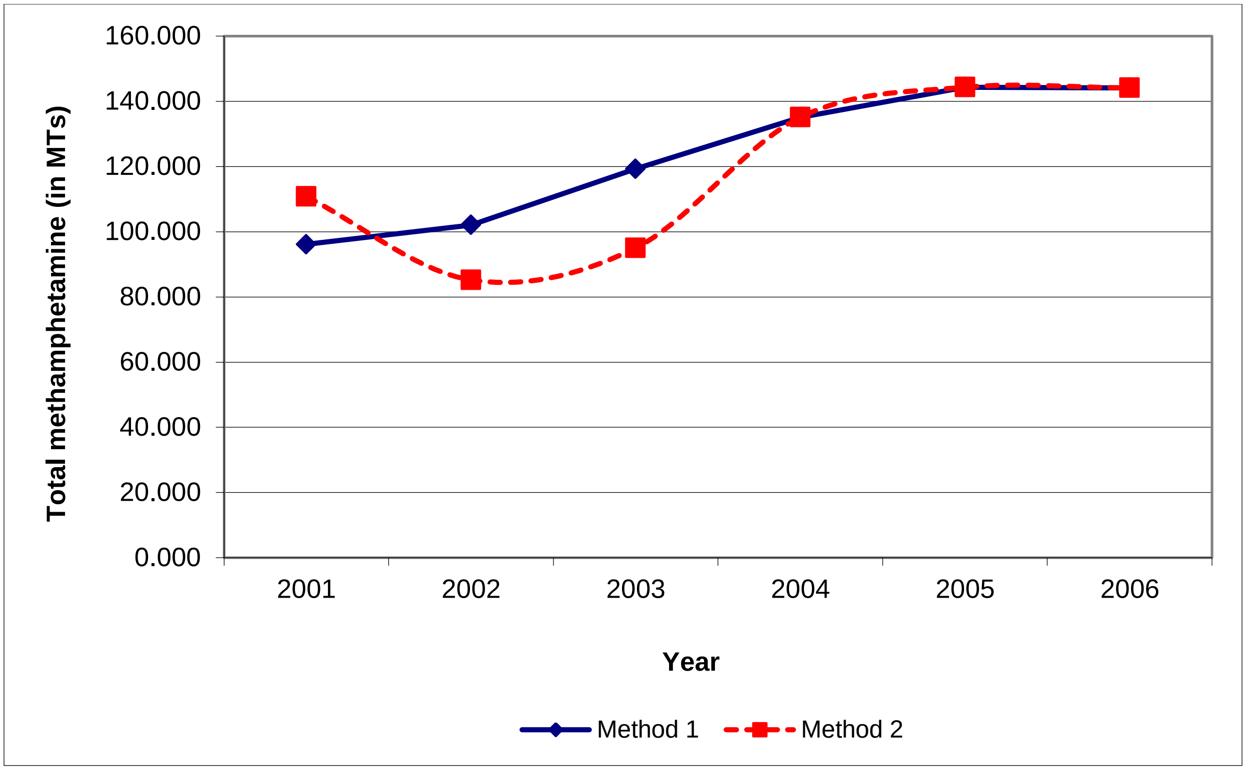
Methamphetamine

The supply of methamphetamine to the U.S. market has three components: 1) production of methamphetamine by small toxic labs (STLs) using over-the-counter (OTC) products containing ephedrine or pseudoephedrine (EPH/PSE); 2) production of methamphetamine by domestic super labs (DSLs) using diverted bulk EPH/PSE from the U.S. and Canadian pharmaceutical industry; and, 3) importation of methamphetamine produced outside the United States (mainly Mexico) and smuggled into the United States as finished product.

A single approach is used to calculate the amount of methamphetamine produced by STLs (component 1) and DSLs (component 2): estimated diverted supplies of EPH/PSE products and bulk EPH/PSE are converted to finished product and seizures are subtracted from that quantity. Two separate methods are then employed to estimate the supply of methamphetamine imported as finished product from Mexico (component 3). In the first method, imported methamphetamine is estimated for an anchor year (2004) and then workplace drug testing data are used to develop a non-linear consumption path. From this, domestic production is subtracted and the residual is considered to have been imported. In the second method, imported methamphetamine is estimated using precursor supply statistics to calculate total imported finished product. This second method is applied only to the earlier years of the period studied (2001 through 2003) because reliable information is lacking for 2005 and 2006.

As Figure ES.3 shows, these two methods produce slightly different results for 2001 through 2003: 2001 (107.4 metric tons compared with 96.6 metric tons), 2002 (102.6 metric tons compared with 84.3 metric tons), and 2003 (119.9 metric tons compared with 95.7 metric tons). For the later years of the period studied, the two methods necessarily yield the same results: 135.9 metric tons in 2004, 145.1 metric tons in 2005, and 144.9 metric tons in 2006.

Figure ES.3. Two Estimates of Methamphetamine Availability in the United States (Metric Tons)



The final estimates reveal the changing trends in the U.S. methamphetamine market. Namely, the supply of methamphetamine from STLs and DSLs declined from 2001 through 2006, likely in response to restrictions on both precursor imports and to law enforcement focus on laboratory seizures. Meanwhile supplies of foreign imports of finished product increased, presumably to meet consumer demand.

The Drug Availability Steering Committee characterized its methodology for estimating methamphetamine production as *pending*. The Committee summarized its findings:

> Domestic production is the primary source of methamphetamine available for domestic demand. The largest component of the 110–140 pure metric tons of methamphetamine is manufactured from diverted Canadian and U.S. pseudoephedrine and ephedrine. There is considerable uncertainty in the diversion figures, which highlights the need for improvements in tracking precursor chemicals in order to reduce their use in the manufacture of illegal synthetic drugs.

The Steering Committees estimates for 2001 are slightly higher but not inconsistent with the methodology used in DAEUS. The trouble with the Steering Committee's estimation procedure is that it does not apply to more recent years because of restrictions on precursor chemicals and law enforcement activities to dismantle small laboratory production. DAEUS provides a revised methodology.

Marijuana

The National Drug Intelligence Center (NDIC) (2010, note 16, p. 36) has concluded:

> No reliable estimates are available regarding the amount of domestically cultivated or processed marijuana. The amount of marijuana available in the United States—including marijuana produced both domestically and internationally—is unknown. Moreover, estimates as to the extent of domestic cannabis cultivation are not feasible because of significant variability in or nonexistence of data regarding the number of cannabis plants not eradicated during eradication seasons, cannabis eradication effectiveness, and plant yield estimates.

This report concurs with NDIC's reasoning and conclusions.

Furthermore, this report argues that highly regarded demand-based estimates of marijuana use and marijuana markets show that marijuana use has remained nearly constant during the period of interest for this report. Dramatic increases in supply-based estimates (cultivation, seizures, etc.) are not credible.

The Steering Committee characterized its marijuana estimates as *preliminary* and expressed skepticism about their validity:

> The 10,000 to 24,000 metric ton estimate of marijuana availability was based on a two-part methodology that separately derived the quantities of foreign and domestically produced marijuana available. The speculative estimate of domestic marijuana production was calculated by applying three hypothetical seizure rates to domestic cannabis eradication figures. There is considerable uncertainty in the estimate due to the lack of direct information on the magnitude of the domestic production component. Development of either a cannabis signature to determine the source areas of seized marijuana samples, or a science-based estimate of illegal domestic cannabis cultivation, would significantly improve the accuracy of this estimate.

Comments on the Prospect for Future Estimates

Estimating the availability of illegal drugs to the United States is a challenge. For reasons explained in this report, there exist no credible supply-based estimates for marijuana. Supply-based estimates for methamphetamine have credibility for anchor years, but over time the estimates become increasingly dependent on apparent trends in consumption. Workplace data are not the ideal way to establish those trends, because workplace data are highly selective, but trends in drug treatment broadly agree with workplace reports. Still, methamphetamine estimates are increasingly dependent on trends derived from demand-side instead of supply-side data.

Availability estimates for cocaine are disconcertedly unreliable. Fortunately there are two semi-independent sources: the U.S. Government and the United Nations. Combining estimates from those two sources appear to provide credible estimates of the level and trend in cocaine availability. How much of that cocaine comes to the United States and how much of it goes to the rest of the world is less certain.

Estimates of heroin availability appear to be credible provided conclusions are based on long-term trends. Nevertheless, members of the Drug Availability Steering Committee have expressed concern that production estimates are too low for Colombia and the very large recent increase in Mexican poppy cultivation is difficult to understand. Estimates from the Heroin Domestic Monitor Program are central to the estimation methodology but caution must be used in interpreting those estimates (Manski, Pepper & Petrie, 2001).

Chapter 1: Introduction to the Methodology

This report provides estimates of the amount of illegal drugs available for use in the United States between 2001 and 2006.[6] The basic methodology has been reviewed and approved by an interagency team assembled by the Office of National Drug Control Policy,[7] but this report revises that approved methodology in three regards.

First, aspects of the approved methodology are inadequate because the estimates it produces contradict other evidence about levels and trends in drug use in the United States.[8] The problem is especially acute for estimates of marijuana availability. Where necessary this report explains why the approved methodology does not work and recommends and applies an alternative methodology. To avoid confusion, this report references the alternative methodology reported here as the *ONDCP methodology*.

Second, the approved methodology was concerned with point estimates. A point estimate might be seen as the best estimate of a drug's availability to the United States for a given year, but point estimates can be imprecise. This report assigns measures of uncertainty to those point estimates.

Third, other researchers have estimated the availability of drugs to the United States. Especially prominent is the ongoing work of the United Nations Office on Drugs and Crime (UNODC), of the World Bank and of the Rand Corporation. Works from UNODC, the World Bank, Rand and elsewhere are cited throughout this report, compared with estimates from the ONDCP methodology, and in some instances used to derive uncertainty bounds.

This introductory chapter summarizes ONDCP's approach to estimating drug availability to the United States. The summary is conceptual and it raises issues that reappear throughout the report. Each of the following chapters is devoted to a specific drug: cocaine, heroin, methamphetamine and marijuana. Each of those chapters contains a non-technical body that provides a simple depiction of the computing

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6 For cocaine and heroin, ONDCP provided estimates in a 2009 report, *Major Illicit-Drug Producing Nations: Cultivation and Production Estimates, 2004–2008*. To reduce sampling variance, some of the trend statistics use data through 2008, but tables and figures are through 2006.

7 The methodology was first developed by an interagency team tasked with developing a methodology that had interagency approval (Drug Availability Steering Committee, 2002). Through two separate contracts, a study team from Abt Associates Inc. worked with ONDCP and the Steering Committee to improve the estimates and to codify the estimation procedures. This present report incorporates some additional refinements.

8 The report presents supply-based estimates of the availability of drugs to the U.S. A companion report presents demand-based estimates. Supply-based and demand-based estimates should be in broad agreement, but they are disparate for marijuana and cocaine. One alternative is that the demand-based estimates are at fault, but other indicators of drug use are inconsistent with the marijuana and cocaine demand estimates. The credibility of supply-based estimates is challenged when supply-based estimates are inconsistent with all other indicators.

algorithm specific to the drug of concern in that chapter. Technical appendices provide details and justification.

The rest of this introduction comprises four parts. The methodology approved by the interagency Steering Committee relies heavily on basic accounting to derive estimates of the amount of drugs available to the United States. ***Section 1.1*** (below) is an overview of that accounting methodology. Greater detail appears in subsequent chapters that are specific to cocaine, heroin, methamphetamine and marijuana. ***Section 1.2*** introduces a simple model of the supply and demand for illegal drugs, and uses that model to explain why the accounting methodology can sometimes produce misleading estimates of drug availability and, hence, why the accounting methodology might need to be replaced with a better approach. Subsequent chapters on each of the four drugs use the simple supply and demand framework to produce estimates of drug availability and to reconcile those estimates with consumption-based estimates and other indicators. ***Section 1.3*** turns to the question of how a reader can assess the credibility of the estimates; that is, it raises the issues of validity and reliability. Given an understanding of the issues of validity and reliability, ***Section 1.4*** explains how this report deals with uncertainty in the estimates.

1.1 The Original Methodology: An Accounting Approach

Estimates are limited to four drugs: cocaine, heroin, methamphetamine and marijuana. The accounting methodology for estimating *cocaine* and *heroin* are similar. Calculations begin with estimates of areas dedicated to cultivation of coca and poppies, the basic ingredients for cocaine and heroin, respectively. The estimates are primarily based on satellite and other imagery of fields under cultivation, but additional sources are also used. Estimates of hectares under cultivation are reduced by estimates of eradication,[9] and the resulting potential production of cocaine or heroin is estimated based on studies of crop yields (fresh leaf yield, water content, and cocaine alkaloid for coca and opium for poppy) per hectare under cultivation and studies of the production efficiency of converting coca leaf into cocaine and of converting poppies into heroin. The amount available from production is further reduced by seizures in the source areas (where cocaine and heroin are produced) and in the transit zones (the areas across which the drugs are shipped to their destinations). The residual is available for consumption, but there is one more calculation step—dividing cocaine and heroin available for consumption between the United States and the rest-of-the-world.

This division rests on estimates of cocaine consumption in the rest-of-the-world for cocaine, and for heroin it rests on estimates of the proportion of U.S. heroin consumption that comes from Colombia and Mexico.[10]

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[9] The UNODC estimates adjust for eradication by optimistically assuming a 90 percent kill rate for spray and 100 percent kill rate for manual eradication. The U.S. Government's approach is to estimate hectares without explicit adjustment for eradication; areas imaged after spray and manual eradication will reflect the impact of spray, whereas areas imaged before eradication will not.

[10] Cocaine is produced exclusively in the Andean region, and the U.S. consumes a large proportion of that worldwide production. Heroin is produced in South America, Central America, Southeast Asia and Southwest Asia. The U.S. consumes a small proportion of worldwide heroin production, so the same estimation procedures for cocaine do not work for heroin. Instead, most of the U.S. retail heroin originates from South American and Mexican heroin production, as indicated by the source-signature of retail purchases.

The accounting methodology for estimating *methamphetamine* availability differs from that for cocaine and heroin in two ways. First, the availability of precursor chemicals—pseudoephedrine and ephedrine—replaces coca leaf and poppies as the starting point for calculations. Given estimates of the availability of precursor chemicals, estimates of potential production come from information about the efficiency of the production process that converts precursors into methamphetamine. Seizures are subtracted to yield estimates of the availability for consumption. Estimates of precursor chemicals were available for the baseline part of the study period, but they were unavailable for the latter part of the study period, so the study superimposed estimated trends in methamphetamine production on the baseline measures. Second, methamphetamine has both a foreign production component (principally Mexico) and a domestic production component. Both are taken into account.

The accounting methodology for estimating marijuana availability also differs from the methodology for cocaine and heroin. The basic estimation problem is that marijuana production has both a foreign and domestic component. Estimating foreign production of marijuana is similar to estimating foreign production of cocaine and heroin. However, when estimating domestic production, there is no useful counterpart to hectares of coca and poppies under cultivation, and estimation depends heavily on assumptions about the efficacy of enforcement at eradicating marijuana in the field and at interdicting marijuana as it moves to market. For example, if 1,000 metric tons are eradicated or destroyed, and if enforcement eradicates and otherwise destroys one-third of all production, then there must have been 3,000 metric tons of production of which 2,000 metric tons moved to market. The report demonstrates that this estimation is not a sound basis for estimating domestic production.[11]

While this summary provides an overview of the accounting methodology, calculations are more complicated. The following chapters carry the reader deeper into how this study estimates the availability of cocaine, heroin, methamphetamine and marijuana to the United States. Those chapters spare the reader from reading most technical details; however, readers seeking details should review the technical appendices associated with each chapter.

1.2 Supply and Demand Models

The accounting model, as described in the previous section, does not provide a realistic view of how markets behave. This section introduces a simple, more realistic, model of the supply and demand for illegal drugs.[12] It uses that simple model to argue that the accounting model sometimes produces

11 The National Drug Intelligence Center (2010) has reached a similar conclusion in the National Drug Threat Assessment 2010 with respect to domestic cultivation. From note 16 on page 36: "No reliable estimates are available regarding the amount of domestically cultivated or processed marijuana. The amount of marijuana available in the United States—including marijuana produced both domestically and internationally—is unknown. Moreover estimates as to the extent of domestic cannabis cultivation are not feasible because of significant variability in or nonexistence of data regarding the number of cannabis plants not eradicated during eradication seasons, cannabis eradication effectiveness, and plant yield estimates."

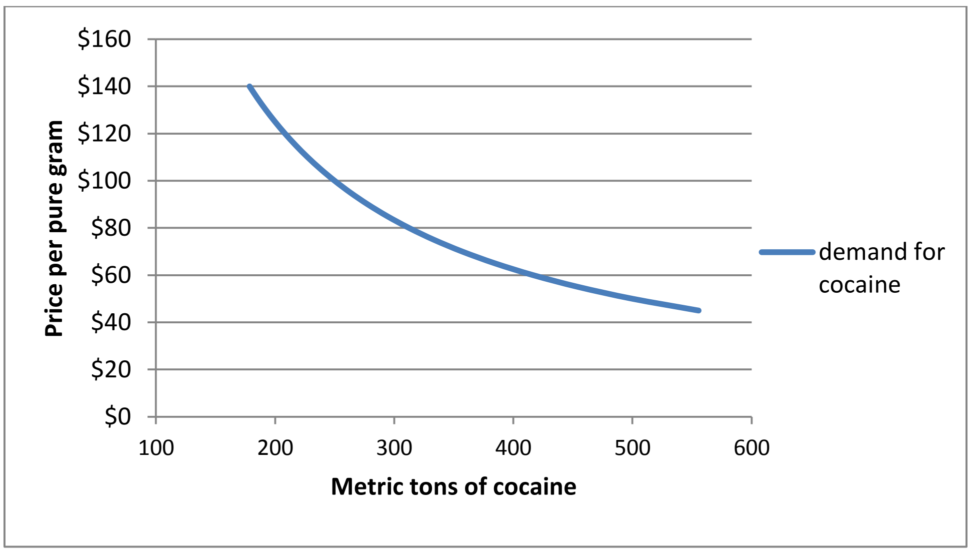
12 Notable economists have argued persuasively that the logic of supply and demand extends to illegal drug markets (Becker, Murphy, & Grossman, 2006; Manski, Pepper, & Petrie, 2001) and have applied economic modeling to better understand the effectiveness of anti-drug programs (Mejia, 2010; Chumacero, 2010).

misleading estimates of drug availability. In addition, applying the simple model to estimating the availability of illegal drugs helps reconcile supply-based estimates with other indicators of drug use.

This section introduces the simple model of supply and demand using an illustration related to how markets adjust to programs that eradicate coca. A similar argument would apply to programs that seize cocaine, and the model can extend to heroin, marijuana and methamphetamine.

In the world of economic modeling, a demand curve expresses the amount of drugs that buyers would purchase conditional on the price of the drug. Figure 1.1 shows a hypothetical demand curve for cocaine. As expected, people will buy more cocaine when prices are low, and they will buy less when prices are high. At a price of $100 per pure gram, people will buy 250 metric tons of cocaine. At a lower price ($50) they will buy 500 metric tons; at a higher price ($125) they will buy 200 metric tons. The relationship between price and amount desired is encapsulated in a theoretical construct called *elasticity of demand*. The elasticity of demand for cocaine is uncertain, but for purposes of illustration, Figure 1.1 assumes that elasticity equals -1.[13] This means that as prices increase by X percent, the amount desired decreases by roughly X percent. More accurately, the elasticity of -1 means the product of price times the amount desired always equals a constant amount of expenditure.

Figure 1.1. The Hypothetical Demand for Cocaine



A supply curve represents the amount of drugs that dealers would willingly sell conditional on the price of the drug. As the figure demonstrates, the accounting model adopts an unrealistic supply curve.

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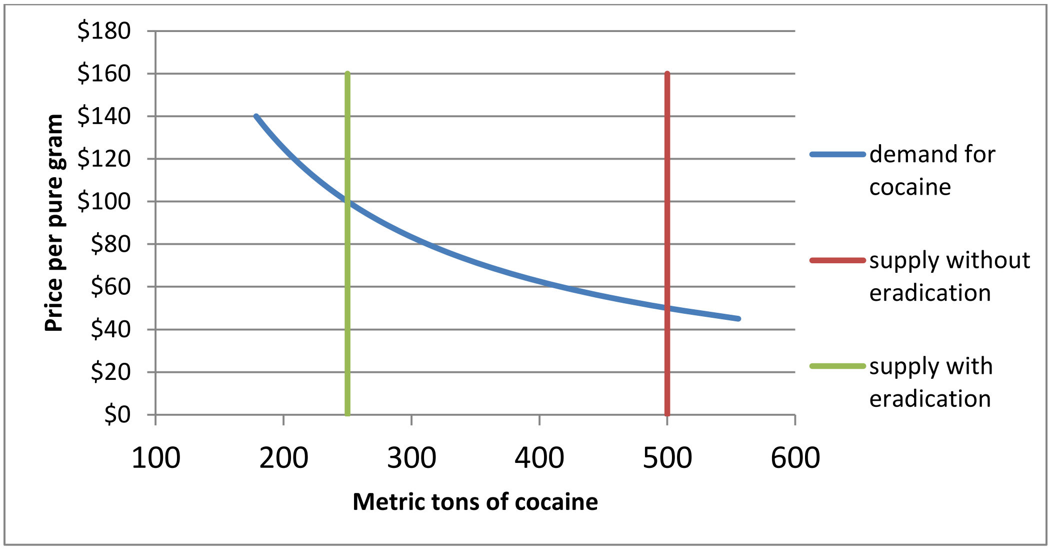
[13] Becker et al. (2006) note that "There are no reliable estimates of the price elasticity of demand for illegal drugs.… However, estimates for different drugs generally indicate an elasticity of less than one in absolute value, with a central tendency of about one-half … although one or two studies estimate a larger elasticity.…" Using economic reasoning and a review of elasticity studies for various goods, Clement (2005) argues that without better information, a researcher should assume that the elasticity is about -0.5. This advice is consistent with elasticity estimates for alcohol and tobacco (Fogarty, 2004; Gallet, 2007; Wagenaar, Salois, & Komro, 2009; Gallet & List, 2003). However, the logic of Figure 1.1 and subsequent figures would not change materially if the argument assumed an elasticity whose absolute value was less than one.

Specifically, absent eradication programs, the supply would be a fixed amount. Figure 1.2 assumes that the fixed amount would be 500 metric tons. A program that eradicates the equivalent of 250 metric tons shifts the supply curve to the left. Thereby the program removes 250 metric tons that otherwise would be available for consumption and, presumably, the remaining 250 metric tons are consumed. Figure 1.2 illustrates the shift from 500 to 250 metric tons. Two things happen. People use less cocaine, and they pay much more per unit of use.

Figure 1.2. Supply and Demand Assuming Fixed Supply

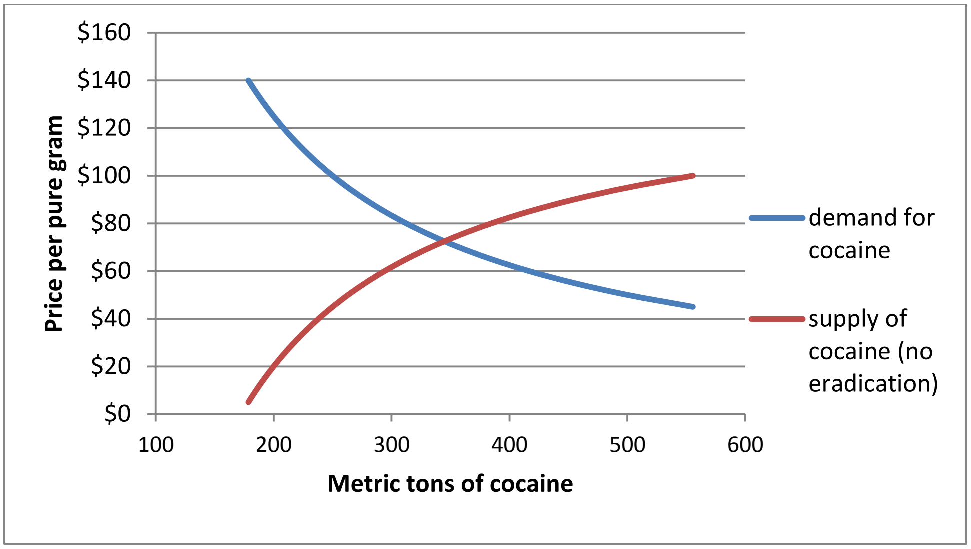


The problem with this supply curve is that it assumes that producers are naïve and their actions are non-reactive. They want to sell 500 metric tons, but they are continually surprised and frustrated by the Government's eradicating half their product. This is a naïve model because there is a simple solution for producers. If they produce 1,000 metric tons, they could sell 500 metric tons, even though the eradication would still eliminate 500 metric tons.

Of course this solution requires that farmers can expand cultivation. In fact, satellite imagery substantiates that new coca fields are continuously appearing (United Nations Office on Drugs and Crime [UNODC], 2010, 2008). The point is that farmers will attempt to adapt to increased eradication by increasing hectares under cultivation within the practical constraints of risk trade-offs, access to markets, climate, terrain, and timing.

Of course, adaptation is costly, and to cover the additional costs, producers may want to produce more than 500 metric tons but less than 1,000 metric tons. Understanding producers' reactions to eradication requires a more realistic supply curve that has a positive slope so that higher prices lead to increased supply. Figure 1.3 shows such a traditional supply curve. A useful way to interpret the supply curve is that it represents the costs of providing cocaine to buyers. In this sense, the cost includes the "profits" that a producer or dealer requires as compensation for the threat of being arrested, prosecuted and incarcerated.

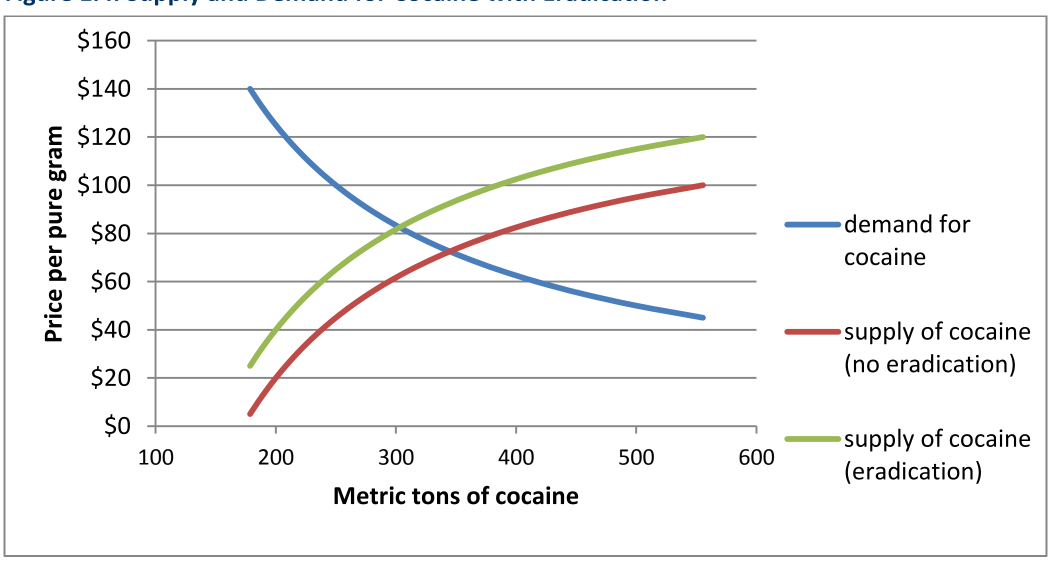
Figure 1.3. Hypothetical Supply and Demand without Eradication



In Figure 1.3, the market clears at a price between $70 and $75 per pure gram and between 330 and 360 metric tons. The term *clears* means that sellers would be willing to provide more cocaine at a higher price, but buyers would be unwilling to buy more cocaine at a higher price, so a higher price and lower amount is untenable. Buyers would be willing to purchase more cocaine at a lower price, but sellers would be unwilling to provide more cocaine at a lower price, so a lower price and higher amount is untenable. The market clears where the demand curve and the supply curve intersect.

Now introduce eradication. Eradication imposes costs to farmers. If half their crop were eradicated, then they could produce as much as they could absent eradication by cultivating twice as much crop. As a first approximation, this would double their production costs. They would pass these additional costs on to agents who buy coca leaf (and base in some places), causing the supply curve to shift upward as shown in Figure 1.4. The market now clears at a price between $80 and $85 and between 290 and 320 metric tons.

Figure 1.4. Supply and Demand for Cocaine with Eradication



But how successful is eradication at changing prices? Kilmer and Pacula (2009) provide some estimates of the cost of cocaine at different stages of production and distribution. The farm gate price is about $650 per pure kilogram equivalent for leaf in Colombia and the retail price is about $120,000 per pure kilogram in Chicago. (This is $120 per pure gram.) If half the coca crop could be eradicated, this would approximately double the farm gate price because farmers' cost would double, so the new farm gate price would be $1,300. The retail price would shift from $120.00 per gram to $120.65 per gram. This represents a negligible shift in the supply curve and a small reduction in cocaine consumption.

How can this be? The Government has removed half the coca crop, yet it has made no more than a dent in the availability of cocaine to the United States. A reasonable conclusion is that farmers have made adaptations. The farm cost has doubled, but the farm gate cost is such a small proportion of the cost represented by the cocaine supply curve that (1) in response to eradication farmers have increased production, and (2) agents who buy coca leaves are willing to pay double the prices because (3) subsequent producers and dealers can easily cover the marginally higher costs.

Farmer response is logical, but nevertheless, is there any evidence that farmers have made the expected adjustments? The evidence is compelling (Mejia & Posada, 2008; UNODC, 2008, 2010). UNODC reports that farmers have frequently moved their fields and taken other action to evade eradication or to minimize the damage. UNODC reports that as eradication has become increasingly effective in Colombia, production has shifted to Bolivia and Peru, and the U.S. Government (2009) agrees that production in Bolivia and Peru has increased over time. The increases, however, are not necessarily as large as the decreases. More importantly, forensic studies indicate that over 90 percent of U.S.-consumed cocaine continues to be sourced to Colombian leaf. Also, UNODC has shown that farm gate prices for leaves and base (a step in the production process sometimes done by farmers) have increased dramatically. The supply and demand model predicts exactly what is observed. In response to higher eradication, authorities observe (see latter discussion): (1) higher farm gate prices, (2) no large increase in retail prices, and (3) no large decline in consumption. A model that assumes fixed supply[14] reduced by eradication (the accounting model) leads to different conclusions that conflict with what is observable about prices and consumption.

There is a complication and possible objection to the model of supply and demand. Without high-placed government sources, farmers cannot increase cultivation in anticipation of expanding eradication, and they cannot reduce cultivation in anticipation of lessening eradication. Farmers are also sensitive to the vagaries of weather. Coca cultivation estimates would fluctuate from year to year. Why does this fluctuation not translate into proportional disruptions in retail markets?

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[14] The supply of cocaine changes from year to year in the accounting model, and in that sense, the accounting model's characterization of supply as fixed is misleading. However, as the term is used here, fixed means that the accounting model makes little accommodation for dynamic responses by farmers and traffickers. The accounting model treats the removal of cocaine as a reduction in cocaine destined for world markets rather than a cost of doing business that leads to adjustments by farmers and traffickers.

The cocaine production estimates are the "potential," or average production expected based on historical harvest trends. These expected yields are not necessarily the actual yield due to many factors occurring in the months following the estimate.

While fluctuations in coca cultivation are expected, this will not necessarily disrupt supply to the same extent, another factor missed by the accounting model. It seems likely that when cocaine is scarce—meaning that buyers are willing to pay a price that exceeds production costs—producers will move product more quickly to market. Variations in movement are bounded, however, within the practical aspects of risk trade-offs, product availability, transportation resources, and prices. When cocaine is abundant—meaning that buyers are only willing to pay a price that is less than the cost of production—producers may delay moving the cocaine to market. Rational behavior will cause suppliers to attempt to smooth the supply of cocaine to market, so that fluctuations in production may not translate into proportional fluctuations in consumption.[15]

Although it may increase risks and costs, quickening and slowing the movement of cocaine to market is one rational adaptation to the vagaries of enforcement and weather. Overproduction is another possible adaptation. To explain, consider a simple illustration. Returning to Kilmer and Pacula's estimates, suppose that dealers as a collective earn $120,000 per pure kilogram of cocaine sold at retail. Suppose that they would like to sell 250 metric tons, so that total earnings are $30 billion dollars. Suppose that eradication disrupts supply, so that dealers can only sell 240 metric tons, and consequently lose $1.2 billion in earnings. Acting as a collective, they could insure themselves against this loss by paying farmers to overproduce.

Suppose that farmers were induced to overproduce by the equivalent of 100 metric tons, an amount that would seem to be more than adequate for insurance. Again using Kilmer and Pacula's estimates for farm gate prices, this insurance policy would cost $65 million, much less than would be lost in dealer revenues. Although UNODC reports refer to excess production that was either stocked or lost in transit (UNODC, 2010, p. 70), U.S. intelligence sources are skeptical that traffickers take these adaptive steps. Nevertheless, cocaine's long distribution chain from South America, through the transit countries, across the U.S. border, within the U.S. highway system, finally reaching the retail market does provide for many points of contraband consolidation, which would result in a system capacity that would dampen the effect of disruptions.

Although there are powerful incentives to smooth the flow of cocaine and other drugs to market, a question remains: Can policy analysts observe significant year-to-year variation in the production potential for cocaine so that an analyst might test for how disruption in production affects distant retail markets? The chapter on cocaine will lead to a sobering conclusion, namely, potential production estimates are measured with such uncertainty that year-to-year comparisons with distant retail markets are challenging. A more useful approach is to focus attention on long-term changes in cocaine supply, because these can be estimated with much greater precision than can short-term changes.

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[15] These adaptations do not require a central authority—such as a dominate drug cartel—for operation. If higher prices emerge, dealers with drugs are motivated to move their product to market. If prices are depressed, then dealers will be less inclined to move product to market. No central planning authority need tell dealers how to achieve their best interests.

The supply and demand model is especially useful when focusing on long-term changes because elapsed time allows farmers, manufacturers, traffickers and dealers to adapt to anti-drug interventions. There are two reasons why this report focuses on long-term trends. The first is pragmatic: This report will show that data are inadequate to reach conclusions about year-to-year variation in the availability of cocaine (and other drugs) to the United States. An attempt to reach conclusions about short-term changes leads to vacuous statements and often to irreconcilable inconsistencies between supply-based estimates and demand-based estimates. The second reason is specific to public policy: An important policy question, and perhaps the most important policy question, is how the supply of cocaine to the United States has trended over time.

Thus, this report proposes an alternative way of estimating and interpreting drug availability. It uses an economic model of supply and demand to structure estimation and interpretation of the amount of drugs available to the United States. It treats short-term changes as unknowable because of large measurement errors. It treats long-term trends as the most important barometer of drug availability, both because long-term trends are measurable with acceptable precision, and because long-term trends may be the most policy-relevant measure.

1.3 Credibility of the Estimates

Estimating drug availability raises challenges. Drug producers and drug distributors avoid being studied for reasons that are obvious. Furthermore, the process of getting close to study subjects is dangerous, and researchers must make accommodations. Therefore, estimation raises both validity and reliability challenges. A *validity challenge* arises when there is a question about whether the estimation methodology measures the correct thing. For example, when researchers question traffickers about contraband load sizes, traffickers who willingly talk may misrepresent the majority of traffickers who are unwilling to discuss contraband load sizes with researchers. A *reliability challenge* arises when the estimation is imprecise. For example, traffickers who are willing to talk may represent all traffickers, but they may provide estimates that are inaccurate—correct on average but not very accurate simply because the traffickers cannot reliably report the metrics (pure metric tons) required by the researcher.

This report provides estimates of the goodness of the estimates—hereafter called uncertainty. When a statistician speaks of uncertainty, he or she usually represents uncertainty with a probability-based confidence interval. Constructing a confidence interval requires knowledge about the sampling distribution of the thing being estimated—for example, the sampling distribution of the estimated amount of cocaine entering the United States. It is typically impossible to construct confidence intervals for availability estimates using traditional procedures, because the sampling distribution of the component parts of the formulas used to estimate availability is often unknown. This report estimates uncertainty using statistical logic where available and judgment when statistical logic is unavailable. An explanation requires a deeper understanding of reliability and validity.

1.3.1 Reliability

This discussion of reliability begins with an example. At the Crime and Narcotics Center:

> Remote sensing and geographic information system specialists employ state-of-the-art technologies to identify, map, and quantify narcotics crops in key countries. They may travel to

remote areas to conduct field studies in an effort to continuously improve their methods of analysis and often brief policy makers on their unique crop estimates.[16]

For cocaine, *hectares under cultivation* comes from satellite and other aerial photographs of cultivation in growing areas. CNC overlays grids on maps of Colombia, Bolivia and Peru, then uses survey methodology to sample from the grids. Using photographs, CNC analysts estimate the hectares of coca cultivated in each sampled grid. CNC derives an estimate of coca cultivation by dividing the estimates for each grid by the sampling probability and by then summing the results. This is straightforward survey sampling methodology, but it necessarily leads to sampling error. CNC reports the reliability of its estimates by reporting a standard error. When reporting estimates, CNC provides a confidence interval (typically about plus or minus 5 percent of the estimates). This is a standard way of reporting uncertainty.[17]

Other factors used in calculating the potential production estimate, such as leaf yield and alkaloid content, can be obtained from experimental coca fields. Other studies are real-world simulations of the process of extracting cocaine from coca leaves.

Potential production estimates are formula driven: Availability is calculated by multiplying factor A by factor B by factor C and so on. If standard errors were available for each of the factors, one could approximate a confidence interval for production potential. To illustrate, suppose that there are four factors, A, B, C and D. Suppose that the square of the standard errors was known for each as VAR(A), VAR(B), VAR(C) and VAR(D). Suppose furthermore that the four estimates are independent, meaning that the accuracy of any one of the four does not depend on the accuracy of the other three. Then a close approximation for the standard error for the availability A is:

$$SE_{availability} = \sqrt{(A \cdot B \cdot C)^2 VAR(D) + (A \cdot B \cdot D)^2 VAR(C) + (A \cdot C \cdot D)^2 VAR(B) + (B \cdot C \cdot D)^2 VAR(A)}$$

Measurement error in any one component affects the measurement error of the total.

1.3.2 Validity

Knowing the standard errors does not by itself lead to probability-based confidence intervals, because of validity challenges. For a useful discussion specific to cocaine, see Mejia & Posada (2008). The following discussion puts validity challenges into four categories, each of which is discussed below:

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16 https://www.cia.gov/offices-of-cia/intelligence-analysis/organization-1/the-cia-crime-and-narcotics-center.html.

17 Although we use CNC's sampling methodology as an example of a procedure that yields a traditional sampling variation, additional uncertainty enters into the CNC estimates, and that uncertainty is not captured by the reported standard errors. Analysts must inspect images and declare an area as being an active coca field. Analysts are skilled, but images can be difficult to interpret, the timing of the imaging may miss fields, cloud cover may obscure images altogether, and the sampling frame has often excluded areas that produce cocaine. The CNC estimates include more sampling variation than is reflected by the computed sampling variation.

1. Some sources are suspected of being statistically biased, but the size of the bias is uncertain.
2. Drug production is dynamic, so that studies done in one year may yield biased estimates when those estimates are applied in another year.
3. As noted, drugs move from farm to market at a pace that is largely unknown and likely responsive to varying market forces.
4. Some estimates rest on unverifiable assumptions.

Statistically Biased Estimates

Estimates are statistically biased when they fail to represent on average what they are intended to represent.[18] This does not mean that a data collector intends to mislead or that a study was designed to mislead. It simply means that there are limitations to scientific studies. For example, the National Survey on Drug Use and Health (NSDUH) is a highly regarded survey of drug use among members of households. The statisticians who administer the survey seek to provide valid and reliable estimates. But some people who are selected for the survey refuse and are replaced. There is no assurance that the replacements represent those who refuse. Additionally, respondents often lie about their use (Fendrich, Johnson, Sudman, Wislar, & Spiehler, 1999; Harrison, Martin, Enev, & Harrington, 2007), so responses are biased if interpreted as true reports of drug use. For these reasons, estimates from the NSDUH are biased, but NSDUH-based estimates are still a cornerstone of tracking drug use.

Components of the availability estimation algorithm are sometimes suspected of being biased. For example, the United Nations Office of Drug and Crime (UNODC) argues that estimates of production efficiency from the real-world simulation studies overstate production efficiency (UNODC, 2009, p. 47), so UNODC adjusts the simulation estimates downward as a bias correction. The U.N. researchers are not criticizing the integrity of CNC/DEA researchers. They are simply asserting that the real-world simulation conditions used overstate the efficiency of a production process that occurs under less optomistic conditions. This observation is not to say that the U.N. researchers are correct. But it is to say that reasonable people can disagree about bias in production estimates, and this adds uncertainty to the overall estimates.

Perhaps less controversial, researchers perform on-the-ground validation studies in which they visit growing areas to collect samples and interview farmers. These are not random samples, because researchers necessarily select the fields based on a variety of accessibility criteria. At times, these studies will use as a proxy the coca yields and alkaloid content documented in a region that has a similar climate and topography, which could introduce bias into the estimates.

Quantifying the bias is difficult. It may be zero, of course, but more likely it is not zero. The size of the bias is unknowable, but is likely to add a non-negligible measure of uncertainty to the estimates.

Temporal Changes

Producer adaptations to anti-drug interventions are dynamic. For example, coca farmers adapt to eradication efforts by growing replacement seedlings, hiding fields, dispersing smaller fields over a wider

[18] This is an imprecise definition. A statistician would say that a statistic is biased when its expected value differs from the parameter that it is supposed to estimate. The definition given in the text is more intuitive and avoids having to deal with unintuitive terms such as *parameter* and *expectation*.

area, adopting ameliorating steps to reduce the harm from spraying, and moving production to new areas. There are, for example, reports of growing in Ecuador (UNODC, 2010, p. 161) and recently Bolivia and Peru have expanded production to possibly substitute for reduced growth in Colombia.

There are at least three noteworthy illustrations of how temporal changes introduce uncertainty (Mejia & Posada, 2008). As reported later, CNC surveys the known and suspected coca growing areas. For some years, CNC's estimate did not include areas that had cultivated coca but were outside the defined growing area boundaries. A second illustration is that estimation studies are done periodically. Those studies show changes in production efficiency, raising questions about what to assume about production efficiency during those years that fell between study years. As another illustration, law enforcement in the United States seems to have caused marijuana producers to shift production to larger plots in national forests, where the marijuana is grown under a canopy to obscure the farm. Likely this leads to lower yield (a topic discussed in the chapter on marijuana), so yield estimates that come from marijuana grown under nearly ideal conditions overstate production yield.

These observations are not intended to fault any agency for its studies. To the contrary, those studies are impressive, and without them there would be little basis for estimation. The observations are merely intended to indicate that additional uncertainty enters into calculations when estimates based on studies done in one year are used to estimate availability in other years.

Movement to Market

From the accounting perspective, availability estimates are often based on a simple assumption: If X metric tons of drug Y are produced in year Z, then X metric tons of drug Y (net of removals) are available for consumption in year Z. This assumption raises three issues. These issues have already been discussed from the perspective of the supply and demand for drugs.

The first issue is the assumption that the X metric tons will move to market. Mexican marijuana cultivation appears to be far in excess of what could be used by U.S. consumers. A parsimonious explanation is that a large proportion of the Mexican production does not move to retail markets in the United States. Similarly, excess production of cocaine and heroin may not move to market in the United States during the year when the cocaine/heroin is produced. The argument is plausible because production costs are low while distribution costs are high. In a business model, excess production of an agricultural commodity whose availability is subject to both weather and government interventions may be rational behavior. While the first issue is that X metric tons may not move to market, the second issue is that the X metric tons may not move to market *in year Z*. This need not imply stockpiling, for which domestic intelligence agencies have no evidence. However, recent results from DEA studies suggest that cocaine can take 18 to 24 months to move from field to market.[19] It seems that producers and distributors could attempt smoothing the flow of cocaine by accelerating its distribution when it is relatively scarce and by delaying its distribution when it is relatively abundant. These attempts, however, are still constrained by real-world considerations of interdiction risk, conveyance accessibility, and availability of replacement product.

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[19] Personal communication from the ONDCP Steering Committee.

The third issue is that distribution systems are sensitive to disruption, so a model that assumes that X tons of drug Y will move to market in year Z can be mistaken. Most cocaine and heroin from South and Central America is moved across the Mexican border by Mexican cartels. During the recent past, those cartels have fought among themselves, restricting the flow of drugs into the United States. Although recent disruptions in Mexico seem exceptional, past disruptions in the Colombian cocaine cartels had similar effects, and it is likely that smaller scale disruptions temporarily impede the flow of drugs into the United States.

The implication is that estimates of the production of a drug can be perfectly precise and yet the estimates of how much of the drug eventually moves to market and when it arrives in the United States can be far from the mark.

Readers should be aware that CNC and DEA are careful to reference their estimates as *production potential*. In the accounting methodology, and in many discussions, production potential minus seizures and other removals is interpreted to be *drug availability*. This is only correct if drugs move instantaneously to market and that is not feasible. An availability model—in contrast to a potential production model—requires some device for distributing production over time.

Assumptions

U.S. intelligence agencies have performed commendable work to measure factors that enter availability estimates. The existence of validity and reliability challenges is common to almost all scientific research and is true in this case as well. Estimates rest on assumptions that are difficult to test, and unverifiable assumptions add more uncertainty to estimates.

For example, suppose that cocaine production was measured precisely. Modelers would still face the problem of determining the proportion of cocaine that goes to the United States and the proportion of cocaine that moves to the rest-of-the-world. There are little data supporting a conclusion. As another example, estimates for marijuana depend on assumptions about the rate at which marijuana is eradicated and seized. There are simply no credible estimates of the rate at which domestic marijuana growing areas are eradicated, and no evidence of how those rates change over time.

Assumptions are unavoidable, though researchers want to avoid assumptions that are so strong yet lacking support that the entire estimation methodology lacks credibility. The chapter on marijuana will argue that the accounting methodology for marijuana estimation falls into this category. At other times the assumptions are strong, but there is a basis for bounding those assumptions and, ultimately, bounding the estimates that depend on those assumptions.

1.4 Dealing with Uncertainty

How good are the estimates given validity and reliability challenges? How can a reader assess the goodness of these estimates? As explained in the subsections below, this report introduces various approaches to assess the credibility of estimates.

1.4.1 Comparing Supply-Based and Demand-Based Estimates

The estimates reported here are *supply-based* in the sense that they represent what drug sellers bring to the illicit drug market. A companion report (*What America's Users Spend on Illegal Drugs*) provides estimates that are *demand-based* in the sense that they represent what users acquire from the market. Expectations are that supply-based estimates should be consistent with demand-based estimates, else one or the other, or perhaps both, is erroneous. Thus one test of the supply-based estimates is whether they agree broadly with the demand-based estimates. This report will provide a summary of demand-based estimates supporting this comparison.

It is also useful to compare trends in the supply-based estimates with trends in other drug use indicators. The United States sponsors quality surveys of drug use among the general population (National Survey on Drug Use and Health) and special populations (the Arrestee Drug Abuse Monitoring survey, the Monitoring the Future Survey, and the Youth Risk Behavior Surveillance System). Each of these surveys has its own limitations, but when *multiple* independent indicators of drug use agree about drug use prevalence trends, one would expect trends in availability estimates to be consistent with them. Of course, one might continue to argue that the availability estimates are credible while the drug use indicator data are faulty, but consistency across multiple independent drug use indicators undermines this argument.

Given the laws of supply and demand, a large increase in the supply of drugs should increase purity and decrease real prices, presuming that demand has remained constant. Likewise a large decrease in drugs should decrease purity and increase real prices. Drug prices provide a useful indicator for testing trends from availability estimates, and fortunately there are sources for price data. The Arrestee Drug Abuse Monitoring survey provides useful data about price trends for marijuana.[20] The National Survey on Drug Use and Health also provides exceptionally good data about trends in the prices for marijuana. Although the System to Retrieve Information from Drug Evidence (STRIDE) has critics (Manski et al., 2001), STRIDE data are used frequently to derive trends in prices for cocaine and heroin and perhaps for methamphetamine and marijuana. All three sources have limitations, but again, when they provide a common perspective on trends, and when those common trends disagree with trends according to the availability estimates, one must call the availability estimates into question.

1.4.2 Alternative Studies

A different approach to assessing the goodness of estimates is to compare them with estimates from other sources. One alternative source is studies from UNODC. Researchers from UNODC have done studies of cocaine cultivation in the Andean region. U.S. Government sources argue that the UNODC estimates are not comparable to the CNC estimates, but nevertheless, they provide another way of looking at cocaine availability. UNODC also does studies of the availability of other drugs, but these provide less useful bases for comparison because the UNODC focus is on worldwide availability instead of availability to the United States. For example, most heroin used in the United States comes from Colombia and Mexico, but these two sources are a small fraction of worldwide supply. Because UNODC estimates for marijuana and methamphetamine are worldwide, they provide no strong basis for inferring availability to the United States.

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[20] ADAM asks questions about prices paid for all drugs, but reported prices do not correct for purity. The primary way that retail prices vary is due to purity. That is, nominal prices remain constant, while purity varies, so that price per pure gram varies. ADAM cannot report price per pure gram.

Other studies have provided estimates for cocaine, heroin, marijuana and methamphetamine. These will be mentioned in the relevant chapters.

1.4.3 Sensitivity Testing

Still another approach to testing goodness is to admit that estimates are measured with error and deduce the size of that error. Statistics provide a way to infer probability-based confidence intervals, but availability estimates often lack standard errors necessary to derive confidence intervals. Instead, the researcher has to provide a subjective assessment of measurement errors that factor into the calculations. Although popular, this approach is often unsatisfying when it leads to uncertainty ranges that are so broad that they lack policy relevance.

This report will sometimes resort to sensitivity testing, but when there is no compelling basis for placing an acceptably low and high bound on an unknown parameter, the more prudent course of action may be to say there is little basis for a credible availability estimate.

1.4.4 Errors in Levels vs. Errors in Trends

Much of this report makes statements about *levels*. For example, the report might say that 250 metric tons of cocaine was available for distribution in the United States during 2006, or it might say that 20 metric tons of heroin was available for distribution in the United States during 2006.

This report also makes statements about *trends*. For example, the report might say that cocaine availability fell by 10 percent between 2005 and 2006. Or it might say that heroin availability fell by 15 percent between 2001 and 2006.

Statements about levels can be much more uncertain than statements about trends. To explain, suppose that uncertainty about cocaine availability has two components. One component varies from year to year. CNC's estimates of hectares under cultivation have sampling error, for example, so in some years the estimates are too high and in other years the estimates are too low. Presumably they are correct on average. A second error component is constant from year to year. Suppose for example that a hectare of coca produces 100 grams of cocaine on average but that official estimates are 110 grams on average. Because of this second error component, the estimates will always have an upward bias of 10 percent. Both components affect uncertainty when estimating levels; only the first component affects uncertainty when estimating trends. Furthermore, the first component will have a comparatively large effect when estimating short-term trends, but a relatively smaller effect when estimating long-term trends.[21]

The report employs this distinction between uncertainty in levels, uncertainty in short-term trends, and uncertainty in long-term trends when those distinctions are useful for drawing inferences about the availability of illegal drugs to the United States.

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21 The intuition is that estimation of a short-term trend may rely on as few as two data points. Estimation of a long-term trend may rely on many more data points. In this context the availability of more data will reduce uncertainty.

1.5 Summary

The following chapters provide availability estimates and uncertainty intervals for cocaine (Chapter 2), heroin (Chapter 3) and methamphetamine (Chapter 4). The chapters are organized so that readers just looking for the estimates need read no more than the beginning of each chapter. Readers interested in understanding the estimation methodology and judging the credibility of the estimates should read the entire chapter. Readers who seek technical details should read the appendices.

The marijuana chapter (Chapter 5) is different. The argument is that the approved methodology is not adequate. The chapter offers evidence about trends in marijuana availability, but it does not provide estimates of the level of marijuana availability other than those provided by demand-based estimates.

The appendices were developed under an earlier contract. They used data that were extant at the time of that contract. Many of the estimates that appear in the chapters were updated under this current contract. Consequently, readers will sometimes find a slight difference between the numbers reported in the appendices and the numbers reported in the chapters.

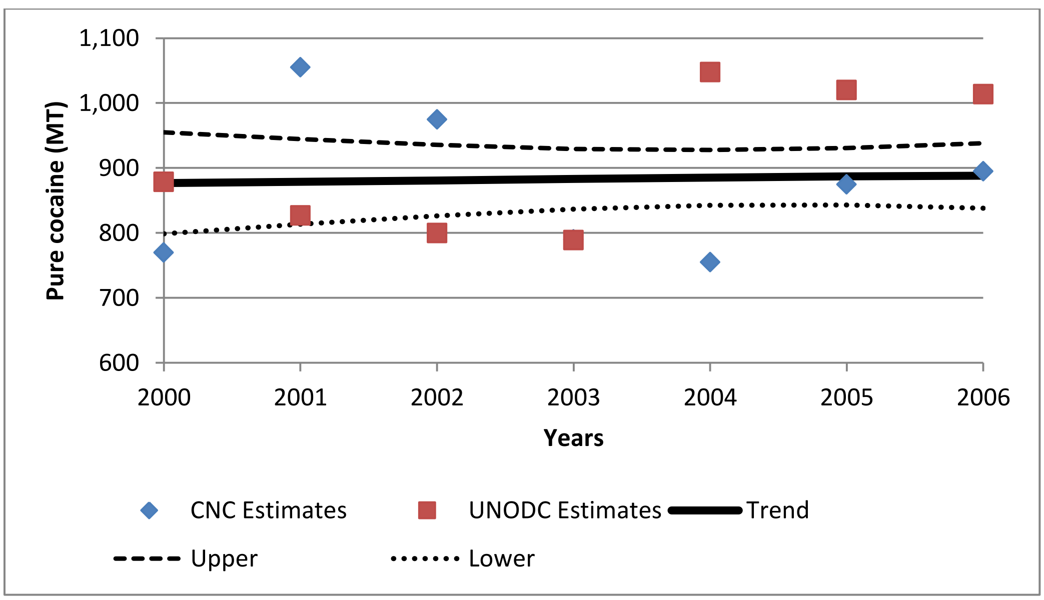
Chapter 2:
Availability of Cocaine

2.1 Summary

This chapter presents estimates of the availability of cocaine to the United States. The estimation entails three consecutive steps: 1) estimate worldwide pure cocaine production after coca eradication; 2) subtract worldwide seizures; and 3) proportion net cocaine production between that destined for the United States and that destined for the rest-of-the-world. The following summarizes the results of these three steps in three respective figures; subsequent subsections provide details.

Figure 2.1 shows the results of the first step—year-by-year estimates of potential production defined as the amount of pure cocaine that could be produced after coca eradication but before seizures of cocaine and cocaine equivalents.[22] The diamonds report year-by-year estimates provided by the Crime and Narcotics Center (CNC) and the squares report year-by-year estimates provided by the United Nations Office on Drugs and Crime (UNODC). The solid line represents long-term trends. The upper and lower broken lines represent 95 percent confidence intervals for the long-term trend, meaning that the true trend is likely to be a line that fits somewhere within the band delineated by the broken lines.

Figure 2.1. Trends in Andean Production of Pure Cocaine (Metric Tons)



Year	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*
CNC	770	1,055	975	790	755	875	895
UNODC	879	827	800	789	1,048	1,020	1,014
Average	825	941	888	790	902	948	955

Note: Estimates for 2003 overlap.

[22] Cocaine equivalents are products from the intermediate stages of cocaine's production: coca leaves, paste and base.

The figure suggests that the potential production of cocaine has been fairly constant at about 880 metric tons per year during the period of interest. Likely there are year-to-year fluctuations due to eradication and the vagaries of weather. **However, as explained in the body of this report, these year-to-year variations are difficult if not impossible to distinguish from measurement error.**

Figure 2.2 shows trends in cocaine available to the world, the second step in the estimation of cocaine availability. These linear trends represent a smoothed version of potential production (shown in Figure 2.1) reduced by an estimated seizure rate. Figure 2.2 does not add any uncertainty due to imprecision in the estimation of seizures although clearly there is uncertainty. Not all seizures are recorded, and some may be recorded more than once. Moreover, cocaine exported from the producing nations is not pure, and the purity has been declining over time, so estimating pure metric tons of seizures is imprecise.

Figure 2.2. Trends in Worldwide Cocaine Availability after Seizures (Metric Tons)

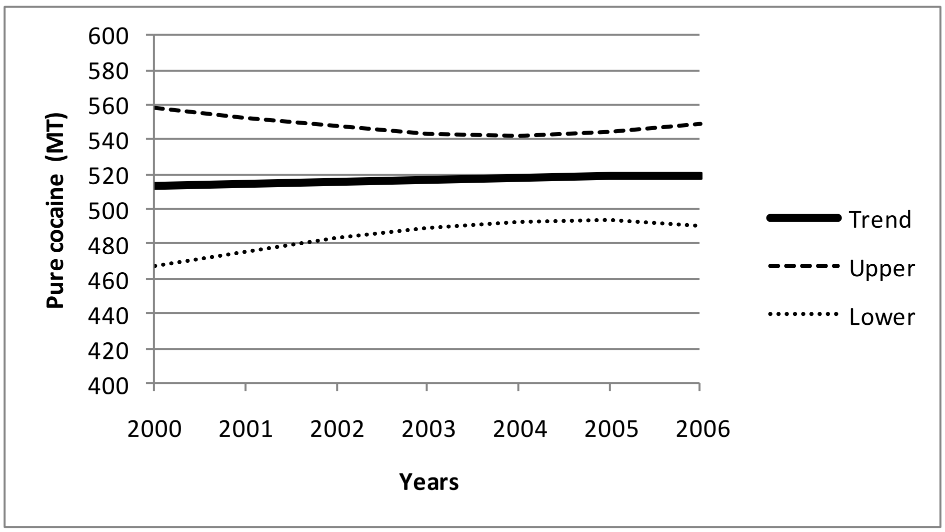


Figure 2.2 displaces the trends and limits in Figure 2.1 to account for UNODC estimates that about 42 percent of cocaine is seized each year before it reaches domestic and foreign markets.[23] Accepting Figure 2.2 as providing the best estimates given available data leads to the conclusion that about 520 metric tons of cocaine was available for consumption. As illustrated by the broken lines, the estimates could be 20 to 40 metric tons smaller or larger, and perhaps unknown errors should inflate this confidence band.

Some cocaine is destined for the United States and some is destined for the rest-of-the-world. Evidence is strong that U.S. demand has been about constant or even declining over the period of interest, while

[23] Estimates come from the World Drug Report 2009, page 70. The UNODC reports: "In 2007, the global interception rate was above the 40% benchmark for the third year in a row. It was calculated at 41.5% for the year 2007, that is, practically the same as in 2006 and 2005 (around 42%)." In footnotes 1, the World Drug Report 2009 explains that the interception rate is "…calculated as the total seizures over total production." In footnote 2, the report explains that these calculations were done after converting production and seizures to pure amount equivalents.

demand in the rest-of-the-world has increased (UNODC, 2010). This suggests that the U.S. share of worldwide production has decreased, but both the proportion of cocaine destined for the United States and trends in that proportion are uncertain. Figure 2.3 adopts assumptions about the proportion of cocaine entering the United States, adds some uncertainty to that proportion, and applies the proportion to the estimates calculated in Figure 2.3.[24] The dotted lines no longer reflect the confidence intervals for the trend, but rather, they should be interpreted as placing a bound on cocaine available to the United States during any specific year.[25]

Figure 2.3. Trends in U.S. Cocaine Availability (Metric Tons)

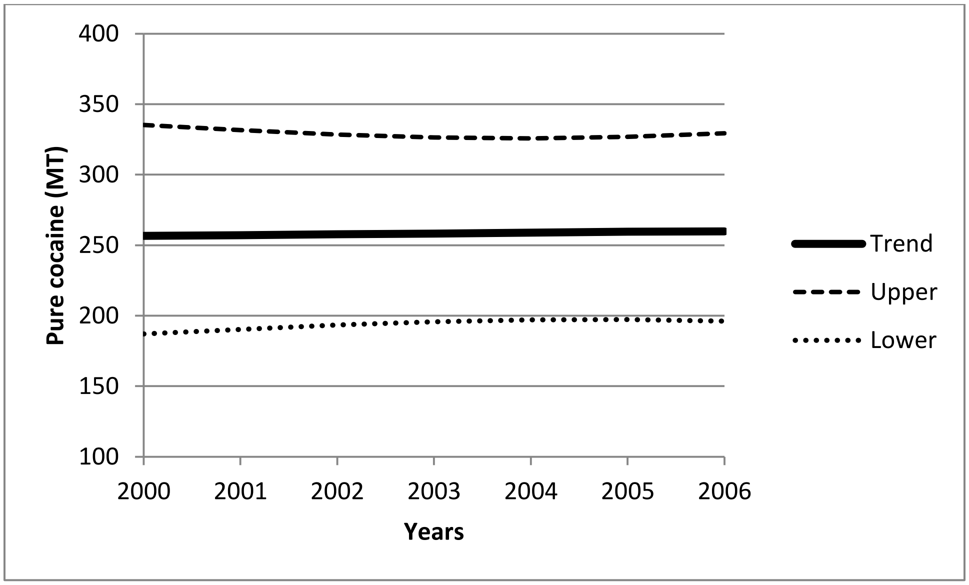


Figure 2.3 suggests that Americans used somewhat more than 250 metric tons per year of pure cocaine during the last decade, but there is a broad confidence interval around this estimate. The low bound is slightly less than 200 metric tons; the high bound is between 300 and 350 metric tons. While the figure implies that U.S. consumption has remained fairly constant, the estimates may not pay sufficient attention to evidence that U.S. consumption has decreased relative to consumption in the rest of the world.

There is an alternative way to derive estimates of cocaine availability to the United States. As described in greater detail later in this chapter, the DEA's Special Testing Research Laboratory (STRL) has completed studies suggesting that most cocaine available in the United States (85 to 96 percent

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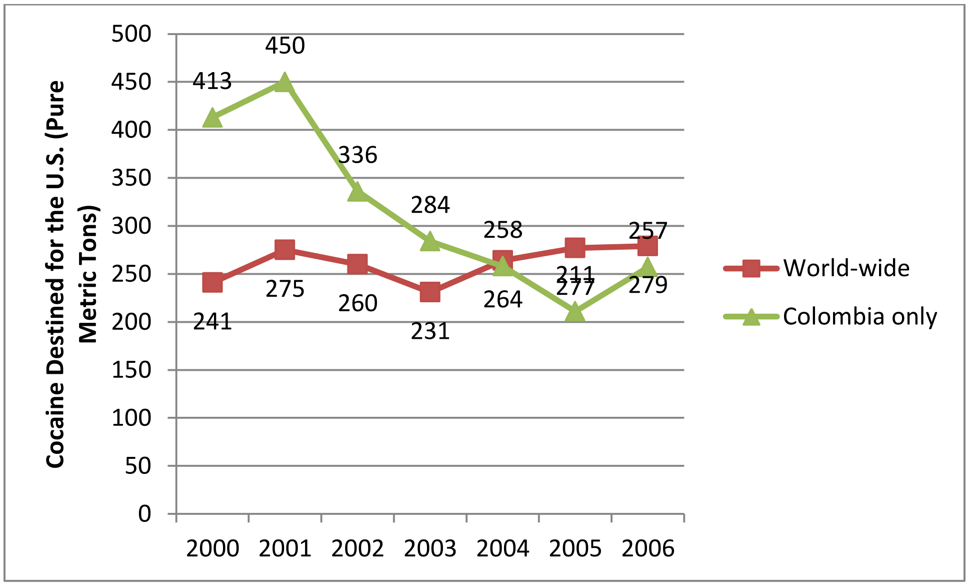
24 Details are provided later in this report. The trend assumes that U.S. consumers account for 50 percent of worldwide cocaine consumption and that the proportion has remained constant over the decade. The upper limit assumes that U.S. consumers account for 60 percent of worldwide consumption and that the proportion has remained constant over the decade. The lower limit assumes that U.S. consumers account for 40 percent of worldwide consumption and that the proportion has remained constant over the decade.

25 Provided the U.S. has continuously used a constant proportion of worldwide cocaine production, the trend and both the upper and lower limits should be scaled according to that proportion. This would shift the lines in Figure 2.2 downward by the same proportion. However, Figure 2.3 is drawn so that the trend is scaled by 0.50, the upper limit is scaled by 0.60, and the lower limit is scaled by 0.40.

between 2001 and 2006) comes from Colombia. As a simplification, presume that all Colombian cocaine is sent to the United States, and adjust the Colombian supply to account for the STRL estimates that 85 to 96 percent of the U.S. supply comes from Colombia. Figure 2.4 graphs these estimates as "Colombia only" estimates. The figure also graphs the "World-wide" estimates that were the basis for the linear trends in Figure 2.3.

Figure 2.4. Cocaine Availability to the United States According to the Worldwide and Colombia Only Methods



These figures are very different for 2001 but thereafter they are similar and they are in close agreement for the last three years. Although this provides some support for concluding that about 250 metric tons of pure cocaine is available for use in the United States, the estimates are not independent since both are heavily dependent on Colombian cocaine production estimates and both are affected by uncertainty in those estimates.

Figures 2.1 through 2.4 understate uncertainty. The CNC and the DEA are responsible for estimating production potential for the U.S. Government. (Hereafter these are called the CNC estimates.) UNODC has a parallel responsibility under commission from the United Nations (hereafter referred to as the UNODC estimates). Both CNC/DEA and UNODC uncover new information that causes them to modify previously reported estimates. Future corrections to extant estimates seem certain, but anticipating the size of those corrections is speculative and Figures 2.1 through 2.4 do not account for that uncertainty.

The rest of this chapter explains the basis for the estimates summarized above. ***Section 2.2*** explains the estimation methodology and presents estimates in three subsections. *Subsection 2.2.1* summarizes the estimates of potential production from CNC and from UNODC. Details for the UNODC estimates appear in UNODC reports (UNODC, 2009, 2010). This subsection explains the derivation *of Figure 2.1: Trends in Production of Pure Cocaine. Subsection 2.2.2* identifies the sources for seizure statistics. After subtracting seizures from potential production, this section leads to *Figure 2.2: Trends in Worldwide Cocaine Availability after Seizures*. Some proportion of that cocaine is destined for the United States. *Subsection 2.2.3* identifies assumptions and provides evidence supporting those assumptions and details the derivation of *Figure 2.3: Trends in U.S. Cocaine Availability*.

Section 2.3 compares the estimates from Section 2.2 against other drug use measures in two subsections. *Subsection 2.3.1* presents cocaine price estimates and discusses whether trends in cocaine prices are consistent with trends in availability. *Subsection 2.3.2* compares supply-based estimates (e.g. the estimates reported in Figure 2.3) with demand-based estimates reported in the companion report *What America's Users Spend on Illegal Drugs* (ONDCP, 2011). Expectations are that the supply-based and demand-based estimates will be consistent else one or the other, or perhaps both, are wrong. ***Section 2.4*** concludes.

2.2 Methodology

This section begins by explaining potential production estimates (subsection 2.2.1). It then adjusts the potential production estimates to account for worldwide seizures (subsection 2.2.2). Finally it partitions the adjusted production estimates into U.S. consumption and consumption in the rest-of-the-world (subsection 2.2.3). Estimates reported here were current at the time calculations were performed. The Government periodically updates estimates, so the estimates reported here may disagree with more recent Government reports.

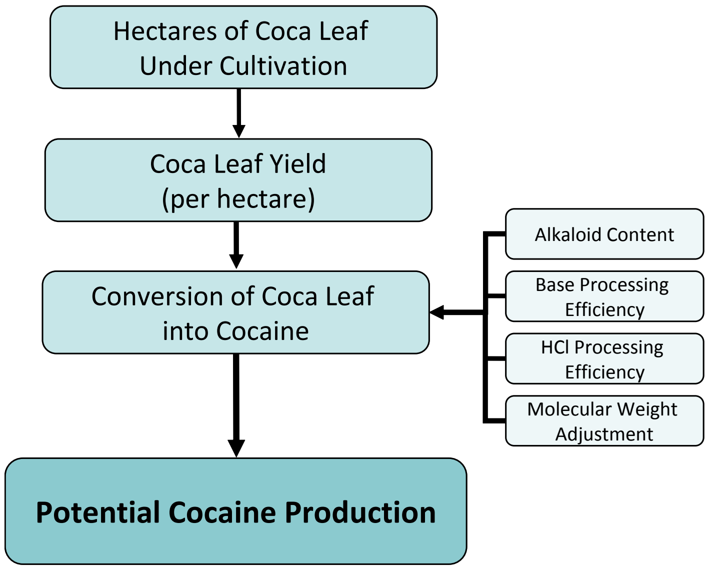
2.2.1 Potential Production of Pure Cocaine

This subsection briefly presents CNC estimates of the potential production of pure cocaine. It then discusses estimates from UNODC. It ends by using the CNC and UNODC estimates to compute trends and confidence intervals for the potential production of pure cocaine.

CNC Estimates of Potential Production of Pure Cocaine

This section discusses the CNC estimation methodology; Exhibit 2.1 illustrates the methodology. As the exhibit depicts, the potential cocaine production is calculated by multiplying the hectares of coca under cultivation by the yield per hectare by a series of factors that quantify the process by which coca leaf is converted into cocaine (alkaloid content, base processing efficiency, HCI processing efficiency, and molecular weight adjustment). The potential cocaine production is calculated for each individual growing area in Colombia, Peru and Bolivia and then summed to get an aggregate of cocaine production.

Exhibit 2.1. Estimation of Potential Cocaine Production



Each of these individual factors depicted in the exhibit and their associated data sources are described in Table 2.1 below.[26]

Table 2.1. Description of Factors Used to Estimate Cocaine Production by CNC

Factor	*Description*
Net Hectares of Coca	The estimates of the net hectares under cultivation for each of the growing areas comes from sample of plots in known growing areas, satellite imagery of those sampled plots, and translation of photographic images into mature hectares under cultivation.[27] Hectares are divided into two subgroups: (1) *Mature hectares* are coca crops that are fully developed. CNC estimates that it takes 1 year for a new planting to become mature in Colombia, Peru, and Bolivia. (2) *New hectares* are fields that are newly planted and are believed to be harvested, but with a limited yield. Plants are considered new in Colombia and Peru for up to 1 year after planting and are estimated to have about one-fifth the leaf yield of a mature plant, depending on the growing area. New growth in Bolivia is considered new for 1 year and is not believed to produce harvestable leaves during that time; thus, new growth in Bolivia has no leaf yield for 1 year.

[26] Prior to 2001, calculations for Bolivia and Peru converted air-dried leaf (rather than oven-dried leaf, which is used in the current formulation) directly into cocaine HCl without going through the intermediary steps detailed here. Because that methodology is no longer used, the old approach is not documented beyond this note.

[27] The authors' understanding of the crop potential production methodology comes from multiple sources. They have benefited from a presentation on October 21, 2003, and a day-long discussion at Abt Associates on December 3, 2003, with CNC representatives. Additional information came from reviewing documentation (CNC slide-show presentations, including a May 2007 presentation: 2006 Colombia Coca Estimates) and Fossum et al. (2002).

Table 2.1. Description of Factors Used to Estimate Cocaine Production by CNC

Factor	***Description***
Coca Yield Per Hectare	The estimate of the annual coca leaf yield from each hectare under cultivation, reported as metric tons per year per hectare, varies by growing areas. The principal sources of data are coca yield studies. Since 1993, researchers have conducted farmer interviews and collected data from coca fields. From this research, analysts estimate the average yield in metric tons of coca leaf per hectare over a full year. Coca leaf yields are divided into two subgroups as follow: (1) The leaf yield for every hectare of *mature crop* under cultivation. (2) The leaf yield for every hectare of *new crop* under cultivation. New coca leaves in Colombia and Peru are estimated to yield one-fifth the product of mature coca leaves.[28] In Bolivia new growth is not believed to produce harvestable leaves, so new leaf yield in Bolivia is zero. Researchers periodically conduct studies to update understanding of current leaf yield estimates. Production factors can change over time as processors begin to discover and use more efficient methods; however, this change is likely to be gradual but the measurement of change is only periodic. Thus, adjustments are made to smooth the trend back prior to the last measurement.
Alkaloid Content	The alkaloid content of coca leaf is measured as a percentage of the leaf weight; alkaloid content—like leaf yield—varies by growing area. The source is the researchers' testing of over 10,000 exhibits of coca leaf collected throughout the Andean Region. As with the leaf yield variable, alkaloid contents also are periodically updated by new studies, which are necessary as the varieties of coca under cultivation change. For each year, the latest available alkaloid contents were used.
Base Processing Efficiency	The base processing efficiency is expressed as a percentage of weight. Researchers have conducted several cocaine laboratory efficiency studies that provide estimates of the average efficiency obtained by cocaine processors in extracting cocaine alkaloids from coca leaf and converting this alkaloid into cocaine base.
HCl Processing Efficiency	Researchers have also conducted a study of the HCl processing efficiency. The study led to an estimate of the efficiency at which coca processors convert base into the salt HCl, the powder form of cocaine.
Molecular Weight Adjustment	A salt molecule is heavier than a base molecule (1.12 times as heavy), so the HCl processing efficiency incorporates a molecular weight adjustment. Although the salt molecule is heavier, the process of extracting the salt from the base is only about 88 percent efficient. Therefore a gram of base yields about 0.986 grams of salt (1.12 x 0.88), in approximately a 1:1 ratio.

Estimating Cocaine Production for 2006: An Illustration

The application of the methodology for estimating cocaine production using 2006 data is illustrated in Table 2.2 below. The table demonstrates the calculation of potential production in the Colombian growing area of Meta-Guaviare (as noted above, the amount of potential cocaine production must be

[28] From 2001 to 2004, CNC used a new-to-mature leaf yield ratio of (1/3):1 for Colombia and (1/5):1 for Peru. However, direct information from several growing areas in Colombia in 2005 and 2006 showed that leaf yield of new cultivation was only between 8 percent and 23 percent of mature leaf yield. For growing areas where no data were available, an estimate of one-fifth of mature yield was used.

estimated in each growing area). The numbers presented are provided for illustration and reflect estimates for Meta-Guaviare obtained from CNC.[29]

Table 2.2. An Illustration: Calculating Cocaine Production in Meta-Guaviare (2006)

Net Hectares of Coca:	31,641 mature hectares were under cultivation. 5,348 hectares of new growth were under cultivation.
Coca Yield Per Hectare:	A mature hectare yielded 5.1 metric tons of coca leaf per year. A hectare of new growth yielded 1.02 metric tons of leaf.
Alkaloid Content:	By weight, a fresh (undried) coca leaf had a 0.149 percent alkaloid content.
Base Processing Efficiency:	The efficiency of converting the alkaloid content into cocaine base was 69.4 percent by weight.
HCl Processing Efficiency:	The efficiency of converting cocaine base to HCl was 88.0 percent.
Molecular Weight Adjustment:	A molecule of cocaine HCl weighs 1.12 more than a molecule of cocaine base.
Total:	**170 metric tons of pure potential cocaine.**

Table 2.3 shows the total estimated cocaine production in Colombia, Peru and Bolivia for years 2000 through 2006. For example, as the table shows, summing across growing areas in Bolivia yields an estimate of 115 metric tons potential production for the whole country in 2006. For the same year, Colombia and Peru have a potential production of 515 and 265 metric tons, respectively; for a total worldwide potential cocaine production of 895 metric tons in 2006.

Table 2.3. CNC Estimates of Andean Potential Cocaine Production

	2000[a]	***2001***	***2002***	***2003***	***2004***	***2005[b]***	***2006***
Cultivated Hectares							
Bolivia	19,600	19,900	21,600	23,200	24,600	26,500	25,800
Colombia	136,200	169,800	144,450	113,850	114,100	144,000	157,000
Peru	31,700	32,100	34,700	29,250	27,500	34,000	42,000
Total	187,500	221,800	200,750	166,300	166,200	204,500	224,800
Dry Leaf Production (MT)							
Bolivia	22,200	32,000	35,000	33,000	37,000	36,000	37,000
Colombia	139,900	180,700	147,900	131,000	123,000	146,000	150,000
Peru	53,100	53,000	58,300	51,200	47,900	53,500	54,500
Total	215,200	265,700	241,200	215,200	207,900	235,500	241,500
Cocaine Production (Pure MT)							
Bolivia	80	100	110	100	115	115	115
Colombia	530	700	585	445	410	500	515
Peru	160	255	280	245	230	260	265
Total	770	1,055	975	790	755	875	895

a Peru cocaine base lab efficiency increased from 44% in 2000 to 72% for 2001-2006

b The area of imaged Colombian growing areas were expanded 81% in 2005 yielding 26% more coca cultivation.

[29] After completion of the analysis phase of this work, the Government revised cocaine production estimates for the Meta-Guaviare area. These revised estimates were not incorporated into the current report; they are not substantial and would not have significantly altered the findings.

UNODC Estimates for Potential Production of Pure Cocaine

The United Nations Office on Drugs and Crime produces annual estimates of cocaine production in Colombia, Bolivia and Peru. Minor production that occurs elsewhere is excluded. This section describes the UNODC methodology (UNODC, 2009, pp. 87–97) and presents estimates.

UNODC assembles satellite images covering almost all of Colombia, Bolivia and Peru. For Colombia during 2008, for example, coverage comprised 98 images. UNODC analysts then apply decision rules to infer whether an area is growing coca and the size of the growing area. Although the rules are sophisticated, they still rely on interpretation. According to documentation, application of the rules "…relies on the profound knowledge of the area by the interpreter. This knowledge is gained though many years of experience analyzing satellite images and frequent over-flights. Interpreters have several years of experience with the project" (UNODC, 2009, p. 94). Visual inspection by plane is used for confirmation.

Some corrections to these estimates are applied by UNODC. When a coca field is manually eradicated, it is reported to UNODC and analysts factor an assumption of a 100 percent kill rate into their estimates to avoid reporting eradicated fields as producing fields. Similar corrections are performed for sprayed fields, except for applying an optimistic assumption that spraying is ineffective for only 9 percent of the fields. UNODC only removes hectares that was manually eradicated or sprayed after the date of the image they use to identify coca. Eradication that occurs before the image date is assumed to be reflected in the image and no further reductions are assessed for that area. Finally UNODC adds a correction for fields that are undetectable because of cloud cover.[30]

Table 2.4 provides estimates from UNODC on three components of the formula used to estimate cocaine availability: (1) hectares under cultivation after accounting for eradication, (2) metric tons of coca leaf after excluding legal growth, and (3) potential production of pure cocaine in metric tons. Readers should consult Table 19 from the UNODC report (UNODC, 2010, p. 162) for details. UNODC warns that revised production efficiency estimates could affect estimates retrospectively, so estimates may change (UNODC, 2010, p. 163).[31]

Table 2.4 provides quasi-independent estimates of cocaine production that can be compared with the CNC estimates presented in the previous subsection. These are not altogether independent, however, because UNODC relies on DEA studies to measure alkaloid content of the coca leaves and laboratory efficiency of extracting the alkaloid and converting it into cocaine (UNODC, 2010, p. 249), and on DEA for

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30 Bias correction based on aerial photography is planned but had not been implemented as of the 2008 estimates. During 2008, the corrections were applied to 17 percent of the estimated hectares (UNODC, 2009, p. 100). UNODC details these adjustments for Colombia but presumably comparable adjustments arise for Bolivia and Peru.

31 Since the UNODC report, the U.S. Government has (1) revised Bolivian potential production estimates upward because coca fields were being harvested at an earlier age than previously assessed, (2) revised Bolivian lab processing efficiency upward, and (3) revised yield estimates for Cusco. Presumably UNODC will revise its cocaine potential production estimates accordingly.

yield estimates in some growing areas (UNODC, 2010, p. 250). UNODC modifies the U.S. Government estimates of laboratory-estimated conversion ratios from base to salt (UNODC, 2009, p. 47).

Table 2.4. UNODC Estimates of Potential Pure Cocaine

	2000	2001	2002	2003	2004	2005	2006
Cultivated Hectares							
Bolivia	14,600	19,900	21,600	23,600	27,700	25,400	27,500
Colombia	163,300	144,800	102,000	86,000	80,000	86,000	78,000
Peru	43,400	46,200	46,700	44,200	50,300	48,200	51,400
Total	221,300	210,900	170,300	153,800	158,000	159,600	156,900
Dry Leaf Production (MT)							
Bolivia	13,400	20,200	19,800	27,800	38,000	28,200	33,200
Colombia	266,200	236,000	222,100	186,050	164,280	164,280	154,130
Peru	46,200	49,300	52,500	72,800	101,000	97,000	105,100
Total	325,800	305,500	294,400	286,650	303,280	289,480	292,430
Cocaine Production (Pure MT)							
Bolivia	43	60	60	79	98	80	94
Colombia	695	617	580	550	680	680	660
Peru	141	150	160	160	270	260	260
Total	879	827	800	789	1,048	1,020	1,014

Table 2.5 compares the total estimates of hectares cultivated, dried leaf yield, and potential pure cocaine from 2000 to 2006 and the average over all years. As the table shows, the CNC and UNODC estimates differ. Between 2000 and 2006, CNC estimates that 196,000 hectares were cultivated each year on average; UNODC estimates that 176,000 hectares were cultivated each year on average. The difference might be explained by CNC's use of higher resolution imagery, which would allow CNC to identify more (presumably smaller) fields.[32] Between those same years, CNC estimates that those hectares yielded 231,000 metric tons of dry leaf each year on average; UNODC estimates 300,000 metric tons of dry leaf each year on average. This discrepancy has no ready explanation, but yield estimates may have much greater sampling variation than has been appreciated.[33] Nevertheless, total product estimates are similar, because UNODC applies lower estimates of production efficiency.[34] According to

32 Although this suggestion was made by CNC reviewers of earlier drafts of this report, evidence is not convincing. CNC and UNODC agree about Bolivian cultivation over the nine-year period. CNC estimates are roughly one-third larger for Colombia and roughly one-third lower for Peruvian cultivation during the same period.

33 Yield estimates require acquiring samples from growing areas. These are difficult to acquire because of the danger of entering areas where producers sometimes use violence to protect their investments. Computing the yield by dividing dry leaf by hectares, the CNC estimate is about 21 percent higher for Bolivia, about the same for Peru, and *somewhat more than half for Colombia*.

34 To approximate yield, pure potential cocaine production is divided by metric tons of dry leaves. CNC estimates are about 16 percent higher than UNODC estimates in Bolivia, about 8 percent higher in Colombia and 56 percent higher in Peru. Presumably UNODC will update its Peruvian estimates given newer yield estimates from the DEA.

CNC, an average of 874 metric tons of pure cocaine was produced each year; according to UNODC, an average of 911 metric tons was produced each year. These differences are not statistically significant.[35]

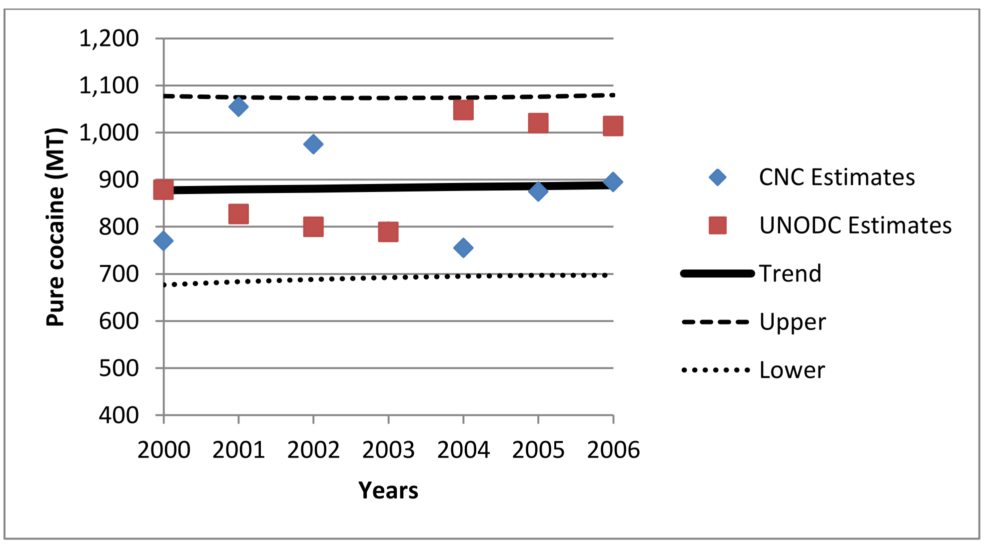
Table 2.5. UNODC and CNC Estimates of Potential Pure Cocaine

	2000	2001	2002	2003	2004	2005	2006	Average
Cultivation (Hectares)								
CNC	187,500	221,800	200,750	166,300	166,200	204,500	224,800	176,000
UNODC	221,300	210,900	170,300	153,800	158,000	159,600	156,900	196,000
Dry Leaf Production (MT)								
CNC	215,200	265,700	241,200	215,200	207,900	235,500	241,500	296,000
UNODC	325,800	305,500	294,400	286,650	303,280	289,480	292,430	196,000
Cocaine Production (Pure MT)								
CNC	770	1,055	975	790	755	875	895	920
UNODC	879	827	800	789	1,048	1,020	1,014	874

Consensus Estimates of Potential Production of Pure Cocaine

Figure 2.5 plots the CNC (triangles) and UNODC (squares) estimates of pure cocaine production for 2000 through 2006. The linear trend suggests that the production of cocaine has been increasing, by about 1.8 metric tons per year, but this trend is not statistically significant.[36]

Figure 2.5. Potential Production of Pure Cocaine (MT)



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[35] The test was based on an ordinary least squares regression. CNC and UNODC estimates were the data points. The dependent variable was metric tons of pure potential cocaine production. The independent variables were a constant, a dummy variable representing the CNC estimates, and a linear time trend. The dummy variable representing the CNC estimates was not statistically significant (p=0.20).

[36] The trend is based on ordinary least squares regression that uses all data points as if they were independently distributed. Data are too sparse to distinguish a linear trend from a non-linear trend.

Year	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*
CNC	770	1,055	975	790	755	875	895
UNODC	879	827	800	789	1,048	1,020	1,014
Average	825	941	888	790	902	948	955

The working hypothesis is that producers will attempt to meet market demand for cocaine and that trends in demand have been roughly linear over the period of interest. Evidence from UNODC (2010) indicates that the demand in the United States has been stable and may have declined during this period, while demand in Europe and the rest of the world has increased. Evidence from other sources indicates that seizures have been increasing, so that even if demand were stable, farmers would have to produce more cocaine to replace what is lost in distribution. There is no strong reason to assume linear growth, but given the data, there is no compelling evidence that growth has followed a more complicated pattern. A linear trend appears to be a good approximation.

Sometimes producers may have produced too much cocaine; sometimes they may have produced too little cocaine. These mistakes seem unavoidable when farmers are uncertain about the intensity and effectiveness of eradication and given that farming is subject to the vagaries of weather. Mistakes partly account for why CNC estimates do not fall on the trend line, but mistakes cannot be the full explanation because CNC estimates often differ materially from UNODC estimates. Clearly measurement error accounts for most of the variation in potential production.[37]

Given statistical logic, about 90 percent of the time the estimates reported by CNC and UNODC will fall within the upper and lower confidence intervals shown in the figure.[38] **The confidence interval is so wide that estimates from any year are not very useful. It seems quixotic to make much of year-by-year changes in potential production regardless of whether the source is CNC or UNODC.[39]**

37 In theory one could make this distinction. The variance about the regression is the total variance from farmer error and measurement error. Looking at each of the six years when both CNC/DEA and UNODCP produced estimates, one can estimate measurement variance alone. One could then subtract the measurement variance from the total variances to derive an estimate of farmer error alone. The problem with this strategy is that the variance are themselves measured with imprecision (and bias) given the small sample sizes.

38 The confidence interval has two components. The first is that there is uncertainty regarding the estimated regression line. Accounting for this uncertainty causes the confidence intervals to bow—the interval is wider at the extremes than it is near the middle of the year distribution. The second component is the measurement error/farmer mistake component that causes variation about the regression line. In addition to linearity, the figure depends on some other strong assumptions, especially that the sum of measurement error and farmer mistakes is distributed as normal.

39 The CNC estimates and the UNODC estimates are based on different methodologies. Each has its own bias and combining them may seem illogical. However, combining them has a strong basis in statistical theory when estimating trends providing each maintains the same estimation methodology over time. The logic is simple. Although the two estimation procedures differ, both provide a valid estimate of trends in availability. Averaging these two trends has a smaller sampling variance than would any single trend estimate. A critic might argue that combining an inferior estimate with a superior estimate would bias the estimate of levels, but this is not necessarily true, because combining the two estimates is likely to have better mean-square error properties given the large sampling variances for the two estimates. At any rate, both the CNC estimates and the UNODC estimates are about the same on average over multiple years. Of course it is possible to judge

Given that year-to-year variation in potential pure cocaine production is measured with such large error, the more useful way to examine these data is to test for long-term trends. Long terms trends are measured with greater precision. Figure 2.1 (shown earlier) reports confidence intervals for the trend line. One interpretation of the confidence intervals is that a reader can be 90 percent sure that the trend is some line bounded by the upper and lower confidence intervals. Some of the allowable trends are positive and some are negative, so the reader cannot be sure based on conventional statistical testing when potential pure production has increased or decreased over the decade. The impression, however, is that it has not changed much.

2.2.2 Availability of Pure Cocaine after Removals

Although the term *seizures* is convenient and conventional, it is not altogether descriptive of a broader concept of *cocaine that is removed from the distribution process*. Clearly a great deal of cocaine is literally seized by the U.S. Government and foreign government agents. Accounting systems are imperfect: some seizures may not be recorded, and some may be recorded more than once.[40] Another problem is that cocaine is shipped to market at varying purities, and although export quality cocaine varies from country to country, evidence is that the trend has been toward higher purity.[41] Seizures of bulk cocaine surely overstate the removal of pure cocaine, and without adjustments, trends are distorted.

Some cocaine is not seized yet still gets removed from the distribution process. Some unknown amount of removal is due to spoilage of a perishable commodity transported under less than ideal conditions. Some happens because traffickers jettison loads of cocaine (generally by sinking them in deep water) to avoid capture by enforcement agents. When that happens, authorities can estimate load sizes based on conveyance types, but they cannot be sure. These lost loads are only approximated.

UNODC Worldwide Seizures Statistics

UNODC has published worldwide seizure statistics, but these are problematic. First, they come from surveys, so there is no way to judge their reliability. Second, they are reported as bulk weight, while evidence is strong that the purity of export quality (EQ) cocaine has increased. UNODC suggests that less than 400 metric tons were being removed early in the decade while more than 700 metric tons were being removed later in the decade.[42]

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trends based on the CNC estimates alone and the UNODC estimates alone. When considered alone, neither trend is statistically significant based on nine years of data.

40 Seizures are often handed off from one enforcement agency to another. Without accounting standards, there is the potential that two or more agencies will take credit for the same seizure.

41 U.S. Government data shows that the quality of export-level cocaine was between 76 and 79 percent for 2000 through 2003 and between 82 and 85 percent for 2004 through 2006.

42 Downloaded from the Internet at http://www.unodc.org/documents/data-and-analysis/WDR2010/Cocaine-seizures.pdf on July 21, 2010. According to the U.S. Government, bulk removals increased from 328 metric tons in 2001 to 492 metric tons in 2006. This is consistent with the UNODC observations.

However, seizures during one year do not necessarily reflect cocaine removed from the same production year. Rational behavior by drug traffickers would be to attempt to accelerate the movement of drugs to market when seizure rates have been especially high (to replace the losses) and to decelerate the movement of drugs to market when seizures have been especially low. These attempts, however, are still constrained by real-world considerations of interdiction risk, conveyance accessibility, and availability of replacement product.

UNODC has estimated that the global seizure rate is about 42 percent of potential production. Except for a three-year interval during which the seizure rate was constant, UNODC does not provide an estimate of how the seizure rate has changed over time, but presumably the long-term trend in seizures has been fairly constant after accounting for variation in the pace of moving cocaine to market.

There is room to be uncomfortable with the UNODC seizures rates. First, is it credible to believe that 42 percent of potential production is seized? Averaging the CNC and UNODC estimates for potential production between 2001–2006 gives an estimate of about 880 metric tons pure. Table 2.6 reports removal statistics for source zone, transit zone arrival zone, and internal to the United States for these same years provided by the U.S. Government.

Table 2.6. Source Zone, Transit Zone and Arrival Zone Cocaine Removals in Bulk (EQ) and Pure Weight (MT)

Description	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*
Source zone	78	112	114	131	160	122
Transit ZONE:	159	153	194	213	270	244
To U.S. markets	141	144	156	197	235	201
To non-U.S. markets	18	9	38	16	35	43
Arrival zone:	74	66	73	74	92	96
U.S.	37	34	35	32	29	33
Non-U.S.	37	32	38	42	63	63
Internal U.S.	17	16	24	22	30	30
Total losses EQ	328	347	405	440	552	492
Average EQ purity	0.76	0.80	0.82	0.84	0.85	0.85
Total losses pure	249	278	332	370	469	418

Sources are the Interagency Assessment of Cocaine Movement (IACM), 2007, and the Cocaine Signature Program.

The source and transit zone statistics include cocaine destined for non-U.S. markets; the arrival zone statistics include non-U.S. arrival zones. Averaging over the six years suggests that seizures are about 353 metric tons pure per year. The simple division of removals by potential production gives a removal rate of about 40 percent.

Long-term trends are more difficult to judge. Table 2.5 shows that removal rates generally increased between 2001 and 2006. By consecutive year the rates are 27 percent, 31 percent, 42 percent, 41 percent, 49 percent and 44 percent. These estimates come from dividing the removal amounts reported in Table 2.5 by the average of the CNC and UNODC estimates reported earlier. The largest proportion of cocaine is removed in the transit zone and the second largest is removed in the source zone.

This raises a question about what should be assumed about removals. There is no question that removals increased from 2001 through 2005. There appears to be no question that removals decreased from 2005 to 2006. Does this mean that traffickers were less able to provide cocaine during the middle part of the decade? Or were traffickers able to adapt by accelerating flow in the middle of the decade and decelerating flow later in the decade?

A complementary explanation is that production of cocaine increased during the middle years to offset increased removals. The measurement error in the potential production data makes it difficult to test this hypothesis. Averaging the CNC/DEA and UNODC estimates for 2001–2003 and then averaging them again for 2003–2006, production increases from 897 to 946 metric tons. Granted this is slim evidence given the measurement errors in these data, but it is consistent with the hypothesis that producers increase production to offset removals.

There are other reasons to question whether the increase in removals was disruptive of drug markets. Later this chapter will examine trends in the price of cocaine, and the pattern is perplexing. To foreshadow, prices were falling during the period when seizures were increasing. Furthermore, cocaine use appeared to increase during these years. Patterns for prices and consumption are consistent with each other but inconsistent with a view that higher removal rates reduced supply.

There is an entirely different explanation for why higher removal rates failed to have a negative effect on supply to the United States. A plausible hypothesis is that removal rates are always constant because the technology of detecting cocaine has not changed much. What matters is that traffickers decided to ship more cocaine over the periods of interest. This would result in more removals. The hypothesis is plausible because the years of interest represent a period of expanding worldwide consumption. This appears to leave a mystery for why seizure rates have recently fallen, but there are three explanations:

- Smugglers are continuously adapting with new smuggling methods and new routes, and enforcement requires time to identify these variations and react.
- Worldwide consumption has recently leveled or even declined.
- Wars among the Mexican cartels disrupted shipments.

Given trafficker adaptability, then, for the purpose of the estimates it seems best to assume that seizure rates have been constant. This is likely wrong, but given that the seizure rates appear to have increased and then decreased, assuming a constant seizure rate probably has little effect on long-term trends in the worldwide availability of cocaine.

Long-Term Trends after Seizures

Accepting that the global seizure rate is about 42 percent of potential production, it is sensible to apply this 42 percent removal rate to the long-term trend and confidence intervals reported earlier. This is equivalent to multiplying the trend and the confidence intervals by 1 – 0.42. Figure 2.2 (already reported in Section 2.1) shows results.

After accounting for removals, the best estimate is that about 520 metric tons are available for worldwide consumption. Based on the confidence intervals, there would be little surprise if the amount were as low as about 480 metric tons or as high as about 550 metric tons. There may be a trend, and it seems reasonable to expect year-to-year variations, but overall trends in removals do not appear to have had a large effect on trends in availability.

2.2.3 Cocaine Destined for the United States

The previous section made the case that about 520 metric tons of cocaine moves to market every year. Possibly this amount has been increasing over time but estimates are imprecise. Taking the 520 as a working number, the problem is to proportion 520 metric tons between the United States and the rest-of-the-world.

There is no strong evidence to support this partitioning (Kilmer & Pacula, 2009, p. 28). UNODC has attempted to estimate worldwide consumption, but their estimates are uncertain because not all countries perform surveys, and furthermore survey results all tend to be for the general population. **The problem is that chronic users are a minority of users but they use a majority of the cocaine.**

According to UNODC (2010, p. 173) people living in North America account for between 32 and 41 percent of cocaine users. These estimates are based on annual prevalence, so they are subject to the problem that they do not represent chronic users, and also, North America combines the United States and Canada. It seems unlikely that U.S. consumption could be as low as 32 percent of worldwide consumption.

Ultimately it is difficult to derive an estimate of the proportion of worldwide consumption that is destined for the United States and even more difficult to estimate trends in that proportion. Perhaps the most justifiable approach is to work backwards from U.S. consumption estimates. These come from the companion report *What America's Users Spend on Illegal Drugs* (WAUSID) (ONDCP, 2011).

WAUSID suggests that Americans used 250 to 350 metric tons of cocaine per year between 2000 and 2003. This is not a probability-based confidence interval, but it seems like a reasonable range to treat as a working definition. If about 520 metric tons are available for consumption worldwide, then a working hypothesis is that Americans use about half of that cocaine. A range of 40 to 60 percent seems plausible. Using that range leads to Figure 2.3 (shown in Section 2.1).

2.3 Comparison of Cocaine Availability Estimates to Other Drug Use Measures

The results summarized in Figure 2.3 suggest that the amount of cocaine available to the United States has remained fairly constant between 2001 and 2006. Is there validation? Price data can be informative because if demand remains constant, a constant supply implies a constant price, other things (such as domestic law enforcement) held constant. Subsection 2.3.1 examines trends in cocaine prices. Another source for validation comes from other estimates, including demand-based estimates. Subsection 2.3.2 compares estimates reflected in Figure 2.3 with estimates from other sources.

2.3.1 Price Trends

The Institute for Defense Analysis (Fries, Anthony, Cseko, Gaither, & Schulman, 2008) produces STRIDE-based drug price series for the Office of National Drug Control Policy (ONDCP). The latest report provides estimates through 2007. (The sources are Tables B-2 and B-3 in the IDA report.)

When estimating prices, it is necessary to distinguish between prices for bulk purchases and prices for pure purchases. For example, a street-level buyer might pay $50 for a gram of cocaine that is 50% pure. The price is then $100 per pure gram. This distinction is essential because nominal prices ($50 in this illustration) tend to remain the same as the purity of cocaine increases and decreases, so there are no large trends in bulk prices. Price per pure gram is a more meaningful metric, because it reflects what buyers pay for what they purchase provided that pure grams are the commodity that ultimately interest buyers.

IDA uses two estimation procedures, both of which are intended to provide estimates of price paid per pure gram purchased. The first is based on *median prices*. The second uses an estimation procedure based on the *expected purity hypothesis* (EPH). Readers should consult the IDA report for details. Estimates for both methodologies are reported in Table 2.7. The table also shows the number of samples used to derive the estimates.

Table 2.7. Price per Pure Gram of Powder and Crack Cocaine for Retail-Level Purchases

	Powder Cocaine (0.1 - 2.0 grams)			Crack Cocaine (0.1 - 1.0 grams)		
	Number	**Median**	**EPH**	**Number**	**Median**	**EPH**
2000	147	$189	$186	187	$243	$252
2001	91	$232	$194	818	$255	$227
2002	85	$165	$137	581	$223	$207
2003	113	$133	$148	444	$210	$188
2004	134	$176	$134	530	$154	$179
2005	124	$138	$132	608	$147	$161
2006	103	$128	$130	664	$147	$153

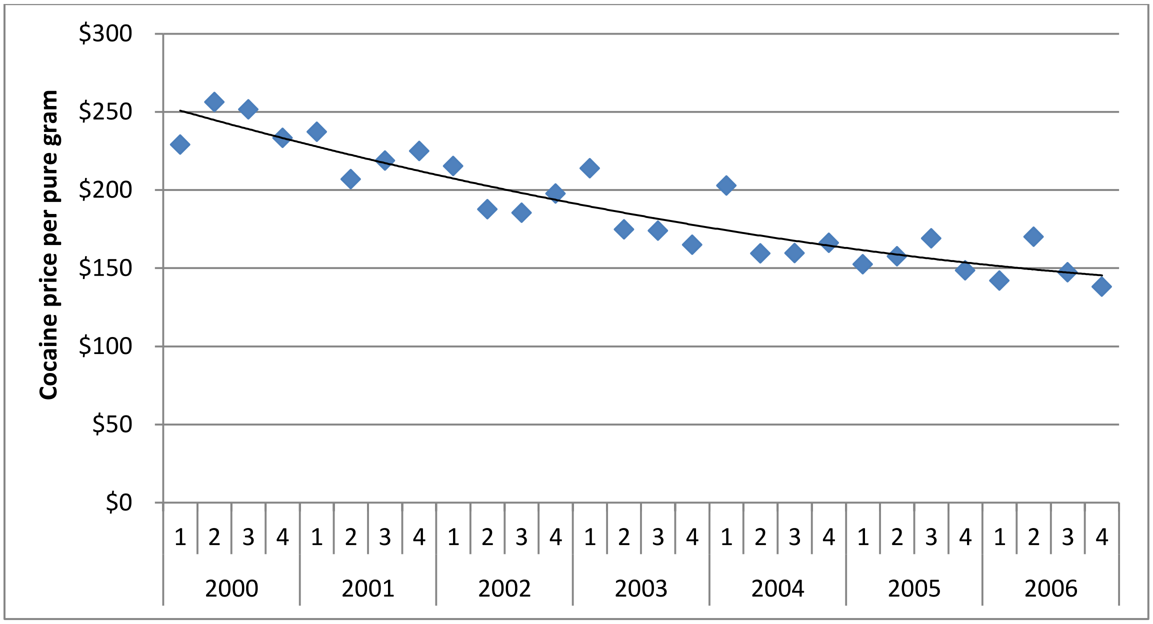
Source: Fries et al. (2008),Tables B-11 and B-12.

IDA produces separate estimates for crack and for powder cocaine. For present purposes (Figure 2.5), they are averaged (using the expected purity hypothesis), with crack cocaine receiving a weight of roughly 0.85 to reflect the fact that about 85 percent of the data are for crack purchases. These estimates are for purchase amounts between 0.1 and 2 grams for powder and between 0.1 and 1 grams for crack exclusive of the lower limit. Arguably these ranges capture most retail-level purchases. Including purchases for larger amounts does not materially alter the findings reported here.

STRIDE-based estimates have been criticized (Manski et al., 2001; Horowitz, 2001): There are seldom reasons for DEA to make street-level purchases, so data are sparse, estimates are consequently imprecise, and they may be statistically biased based on the sampling methodology. In fact, a disproportionately large amount of data comes from the District of Colombia. Nevertheless, STRIDE is the most complete data base of illicit drug price and purity information, but its collection is not random and therefore its use for trends requires analyses (Arkes, Pacula, Paddock, Caulkins, & Reuter, 2008).

Figure 2.6 graphs the estimates from the IDA report. The graph superimposes a curve based on a polynomial regression to provide a visual impression of trends. The figure suggests that prices have fallen over most of the period.

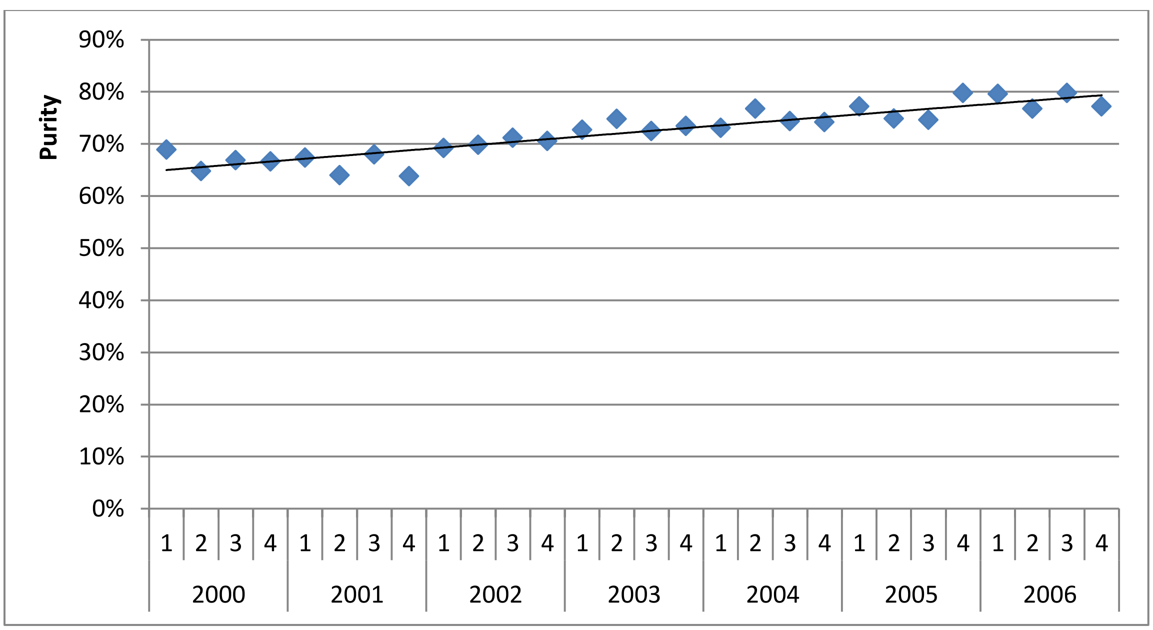
Figure 2.6. Trends in Retail Cocaine Adjusted Prices (Expected Purity Hypothesis)



Source: Fries et al. (2008).

The purity of street-level purchases is another reflection of real prices. Because bulk prices remain fairly constant over time, while price per pure gram has fallen, purity of street-level purchases has increased. Figure 2.7 shows that increase.

Figure 2.7. Trends in Purity of Retail Cocaine Purchases



The price trends are perplexing. Holding demand constant, declining prices imply increasing availability and increased use. Say conservatively that the price fell from $240 per pure gram to $160 per pure gram—a 33 percent decrease. Assuming a demand elasticity of -0.5 implies that use would have increased by about 17 percent in the United States. As discussed in the next subsection, there is little evidence of such an increase between 2001 and 2006.

The price-series provides no confirmation of availability estimates. If anything the price-series implies that cocaine availability has increased. This is generally consistent with estimates of availability from UNODC, except that the timing is wrong. The price decrease happened years after the UNODC estimates started to decline.

Price trends are uncertain outside the United States (see the 2009 U.N. report). One problem is that most non-U.S. price series are not adjusted for the declining purity of cocaine. The second problem is that most price series are not adjusted for exchange rates that have increasingly favored European buyers. UNODC relies mostly on surveys to estimate price trends. The surveys show that prices tended to decrease and then increase in U.S. dollars and decreased in Euros (UNODC, 2009, p. 78).

2.3.2 Demand-Based Estimates

Table 2.8 summarizes statistics reported in the companion report *What America's Users Spend on Illegal Drugs*. The first line reports estimates of the number of chronic users, defined broadly as using on a weekly basis during a reference month. There may have been a slight increase in the number of chronic users, but if so, the increase was not large. Because of changes to the National Survey on Drug Use and Health, there are no estimates for occasional users during 2000 and 2001. An occasional user is one who uses cocaine at less than a chronic level. The estimates are for a reference month. It is difficult to tell because of large sampling variation, but there appears to have been no large increase in occasional use. The third rows shows estimates of expenditures in billions of dollars (unadjusted for inflation). Perhaps there was a modest increase in expenditures, consistent with the modest increase in chronic users, but the increase (if any) is not large. Finally, there is a large estimated increase in tonnage of use. This is because of the apparent decrease in the retail level prices that was discussed in the previous subsection.

Table 2.8. Estimates of Cocaine Use in the United States

	2000	2001	2002	2003	2004	2005	2006
Chronic users (1,000s)	2,578	2,661	2,634	2,812	2,823	2,775	2,777
Occasional users (1,000s)	NA	NA	4,377	5,692	3,728	5,052	4,823
Expenditures ($ billions)	$34.6	$35.0	$35.9	$40.1	$37.2	$37.9	$37.8
Tonnage use (MT pure)	255	228	252	337	346	372	390

Source: Various tables from *What America's Users Spend on Illegal Drugs*

The modest increase in chronic use and expenditures is consistent with the trends reported in Table 2.1. The large increase in tonnage of use is inconsistent with estimates of availability, although it is consistent with an increase in seizures presuming that an increase in removals reflects an increased flow of cocaine to the United States.

2.4 Conclusions

Estimating and tracking the amount of cocaine available for use in the United States is important for formulating anti-drug policy and for tracking the effectiveness of policy interventions. Unfortunately estimation is subject to large measurement error, and only broad conclusions are credible.

Estimates of production potential have more sampling error than is generally recognized. Over the seven-year period, there is no statistically significant difference between CNC estimates and UNODC estimates. But for any year, the differences are large. The 90 percent confidence interval is close to plus or minus 185 metric tons.[43] It does not appear practical to make year-to-year comparisons based on CNC production data.

Estimating long-term trends is more credible, but still not altogether precise. Although cocaine availability appears to have grown at about 1.9 metric tons per year, a 90 percent confidence interval is consistent with an assertion that cocaine could have fallen by 14 metric tons per year or increased by 17 metric tons per year. Furthermore, this presumes that the trend is linear. There is too little data given the large standard errors to refute the assumption of linearity. Of course that does not mean that the assumption is correct.

Estimation ignores knowledge that removals increased and then decreased over the period of interest. A reader can object to that decision, but there is some justification for treating seizures as staying constant at about 42 percent of production. The principal justification is that assuming a constant seizure rates is a useful fiction in a world where (1) producers can increase production over many months (within operational constraints) when cocaine supplies are reduced by shortages and where (2) traffickers can attempt to accelerate the delivery of cocaine to market in response to a shortage and retard the delivery of cocaine to market in response to a surplus. These attempts, however, are still constrained by real-world considerations of interdiction risk, conveyance accessibility, and availability of replacement product. The alternative to the fiction would be to smooth the production potential over years. That 42 percent of the cocaine is seized each year on average seems reasonable given available data about seizures in the source areas and the transit areas.

Determining the amount of cocaine available to the U.S. has greater uncertainty than estimating worldwide availability. There is no way to infer the proportion of cocaine destined for the United States without starting from estimates of domestic consumption and working backward to assume that U.S. consumption is between 40 percent and 60 percent of worldwide production. This is not to say that 40 to 60 percent of cocaine users reside in the United States, but rather, the long-established U.S. markets have produced a disproportionately large proportion of heavy users, and heavy users account for much more cocaine use than moderate users.

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43 There are two ways to derive the confidence interval. For every year, there are two estimates, one from CNC and one from UNODC. Computing the standard error for any year and averaging over the years yields an estimated standard deviation of 113 metric tons. Alternatively, the standard deviation about the regression line is 112 metric tons.

Likely an assumption that Americans have used 40 to 60 percent of the world's cocaine for the entire nine-year period is wrong. The evidence is compelling that use in the United States has stabilized or even decreased over this period while use in the rest-of-the-world has increased. However, the size of the decline in U.S. share is impossible to quantify because UNODC estimates of consumption in the rest-of-the-world are based mostly on scattered general population surveys, and these simply do not account for relative increases and decreases in heavy user populations. Nevertheless, an alternative estimation methodology (the Colombia-only methodology) yields estimates that are similar.

The cocaine price data are perplexing and inconsistent with other evidence of cocaine availability. One might see a commonality between the high prices when UNODC production estimates are relatively low, and low prices when UNODC production estimates are relatively high. However, the *timing* is inconsistent. One would expect a delay between production excess in South America and prices on American streets, yet prices started to fall before production started to increase. Thus there is no correspondence.

The pattern in prices is also inconsistent with removal data. Removals were increasing from 2001 through 2006 and decreasing thereafter. If removals cause shortages, the price patterns should be exactly the opposite of what appears in Figure 2.5. However, there is an alternative credible explanation. Success at intercepting cocaine destined for worldwide markets may be fairly constant over time. If that were true, then increases in seizures may reflect increases in shipments, and increases in seizures would be entirely consistent with increases in cocaine shipped to market and sold at a lower price per pure gram on American streets.

Chapter 3:
Availability of Heroin

3.1 Summary

Although the heroin distributed in the United States originates in four source areas (Mexico, South America—primarily Colombia—and to a much lesser extent, Southwest and Southeast Asia), the model detailed in this chapter relies upon production estimates only from the Western Hemisphere. This partitioning is pragmatic. Most heroin produced in Mexico and South America is destined for the United States. Forensic signature analyses of heroin specimens in the United States indicate that a small fraction of the heroin produced outside the Western Hemisphere is destined for the United States.

Availability is estimated in two steps. First, Western Hemisphere availability is estimated by subtracting source country consumption and total losses from the quantity of heroin produced.[44] Once the availability of heroin from the Western Hemisphere is calculated, estimates of total heroin available to the United States are scaled up to account for heroin that originates outside the Western Hemisphere, i.e., heroin from Southeast and Southwest Asia.

Table 3.1 summarizes estimates that are central to this approach. The top part of the table shows best estimates of the total hectares of Western Hemisphere poppy cultivated for the production of heroin. The source for these data is the U.S. Government. Missing data from Colombia for 2005 were imputed by averaging estimates from 2004 and 2006. No other imputations were performed. The bottom part of the table shows estimates of heroin production (or opiate equivalents). The table also shows a total, which is the column sum.

[44] Estimates of potential heroin production were provided by CNC. These estimates are based on satellite photos of the areas under opium poppy cultivation in each year. A series of production and processing parameters is used to estimate the total amount of heroin that could be produced from these fields.

Table 3.1. Opium Poppy under Cultivation (Hectares) and Heroin Potential Production (Metric Tons)

	2000	2001	2002	2003	2004	2005	2006
Cultivation							
Colombia	5,010	6,540	4,900	4,400	2,100	2,200	2,300
Guatemala					330	100	
Mexico	1,900	4,400	2,700	4,800	3,500	3,300	5,100
Peru						250	
Total	6,910	10,940	7,600	9,200	5,930	5,850	7,400
Pure Heroin							
Colombia	8.7	11.4	8.5	7.8	3.8	4.2	4.6
Guatemala					1.4	0.4	
Mexico	4.5	10.7	6.8	11.9	8.6	8	13
Peru							
Total	13.2	22.1	15.3	19.7	13.8	12.6	17.6

Source: See Table 3.8 and surrounding discussion. Estimates in Table 3.1 capture updates provided by the U.S. Government after the preparation of Table 3.8, so there are small differences between the tables.

Average potential production is about 16 metric tons per year. The trend is not statistically significant.

Table 3.2 reports the percentage of heroin used in the United States by source. As discussed in this chapter, these percentages are based on an analysis of data from the Heroin Domestic Monitor Program (HDMP) and the Heroin Signature Program (HSP). That analysis weights city-specific estimates of heroin potential production areas by a proxy for the amount of heroin used in each city. The table suggests that U.S. consumption is increasingly being met by Mexican potential production.

Table 3.2. Sources of Heroin Used in the United States

	2000	2001	2002	2003	2004	2005	2006
South America	68.2%	61.0%	64.6%	59.3%	45.5%	50.4%	46.1%
Mexico	25.3%	33.9%	31.0%	37.1%	52.5%	45.4%	53.2%
Both	93.5%	94.5%	95.7%	96.3%	98.0%	95.8%	99.4%

Source: See Table 3.6 and accompanying discussion.

This report discusses three ways to estimate heroin availability to the United States based on tables 3.1 and 3.2. The first method is to divide total potential production (minus losses and non-U.S. consumption) in the Western Hemisphere by the proportion of heroin used in the United States that comes from the Western Hemisphere. This is the preferred methods; results appear in Table 3.3. Two other methods, which provide sensitivity testing, are discussed later.

Table 3.3. Tonnage of Heroin Available to the United States

	2000	2001	2002	2003	2004	2005	2006
Western Hemisphere	10.5	19.8	11.8	16.6	10.6	9.9	14.5

Source: See Table 3.7 and discussion. Estimates in Table 3.3 capture updates provided by the U.S. Government after the preparation of Table 3.7. Consequently there are small differences between the tables.

The preferred method (Western Hemisphere) leads to an average of about 13–14 metric tons of consumption per year. There appears to be appreciable measurement error in these estimates because the standard deviation over these six years is 3.7 metric tons. With this degree of measurement error, there is no surprise that the trend is not statistically significant.

Instead of basing the estimates on Western Hemisphere heroin potential production, the estimates could be based on Colombian heroin potential production exclusively or on Mexican heroin potential production exclusively. These two alternative estimates should be the same, but they are very different. The estimate based exclusively on South America heroin leads to an estimate of less than 9.5 metric tons per year with a standard error of 3.2. The estimate based exclusively on Mexican heroin leads to an estimate of less than 22.5 metric tons per year with a standard deviation of 6.5 metric tons. Both alternative estimates differ from the preferred method. This discrepancy raises a question: Why are the three estimates so different?

The estimates of the proportion of heroin from Mexico and from South America may be interpreted incorrectly. The problem may be with a lack of authentic specimens used for the Heroin Domestic Monitor Program, which has often been analyzed (Rhodes, Truitt, Kling, & Nelson, 1998; Manski et al., 2001). The signature program depends on obtaining background intelligence, investigative details, and authentic specimens from each unique production type within source countries. If a source country begins to produce heroin specimens that are forensically similar to an existing production method in a different country, but few or no authentic specimens are collected from the new production method, the signature trends may be misinterpreted.

Still, the finding that Western Hemisphere heroin dominates U.S. markets is consistently maintained between 2000 and 2006, so this finding appears sound and is accepted by other authorities (National Drug Intelligence Center [NDIC], 2010).

Colombian potential production could be underestimated. This is implied by the fact that CNC reports some South American cultivation estimates as "partial." Although Table 3.1 attempts to adjust for underreporting, the adjustment may be incomplete. The Drug Availability Interagency Working Group uniformly supports the possibility that Colombian potential production is understated given the unexplained dramatic drop in heroin potential production as measured by analysis of satellite photography.

Perhaps the best estimate comes from Table 3.3 (Western Hemisphere) because this estimate does not require that U.S. consumption be partitioned accurately between Mexico and South America. This approach suggests that production available to the United States before seizures is about 15 metric tons per year. Still, if Colombian potential production in understated, even this best estimate will be understated. Furthermore, if the HDMP understates use of heroin from outside the Western Hemisphere, the tonnage would be understated.

Assuming that the production of heroin in the Western Hemisphere has been constant over this seven-year period leads to the observation that estimates for any single year are very uncertain. The standard error about a linear regression is 4.0. This implies that in any single year, the observed estimates would have a 95 percent chance of falling within 8.4 and 21.6 metric tons. There appears to be little justification for paying much attention to the estimates for any single year or to changes from one year to the next. Based on the regression analysis, there appears to be greater justification for concluding that the availability of heroin to the United States has not changed much over these seven years.

The subsequent sections provide details on the derivation of the estimates above. The estimation methodology and estimates are described in ***Section 3.2****.* To evaluate the reliability of the estimates, ***Section 3.3*** compares the estimates from Section 3.2 against other drug use measures. Concluding remarks are provided in ***Section 3.4.***

3.2 Methodology

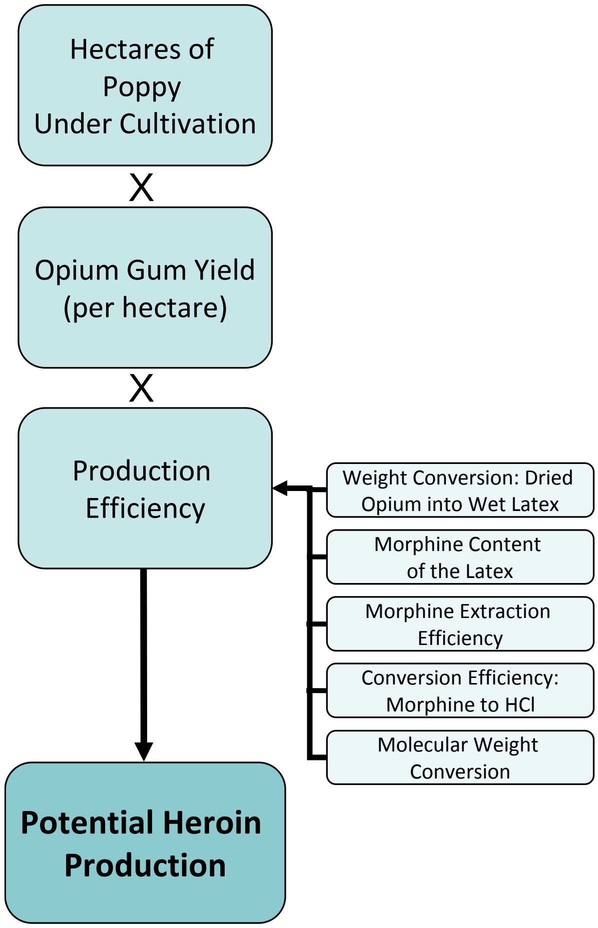
This section first explains CNC's potential heroin potential production estimates from the Western Hemisphere (*subsection 3.2.1*). The potential production estimates are adjusted to account for source country seizures of heroin and consumption and seizures in the United States. *Subsection 3.2.2* describes the calculation of seizure statistics and source area consumption. Finally, *subsection 3.2.3* provides estimates of the amount of pure heroin available in the Unites States based on the proportion of heroin consumed in the United States that comes from the Western Hemisphere.

3.2.1 Potential Production of Pure Heroin

Exhibit 3.1 depicts the methodology for calculating ***the amount of pure heroin that is potentially produced in the Western Hemisphere*** (specifically, Colombia and Mexico) using estimates of poppy cultivation and production efficiencies. Estimates of heroin potential production (the product of the area of poppy cultivation, opium gum yield, and production efficiencies) in the various growing regions in Colombia and in Northern and Southern Mexico are calculated separately and then aggregated to provide an estimate of the potential production in Colombia and Mexico (not shown in the figure).[45]

[45] Processing efficiencies in Mexico are highly problematic given the absence of heroin laboratory efficiency studies in that country.

Exhibit 3.1. Estimation of Potential Heroin Production in the Western Hemisphere



Each of the individual production factors depicted in the exhibit and its data sources is described in Table 3.4 below.

Table 3.4. Description of Factors used to Estimate Heroin Potential Production by CNC

Factor	*Description*
Hectares of Poppy Cultivation	Estimates of the **number of hectares of poppy under cultivation,** in each of the growing areas in Colombia and Mexico, are provided by CNC and are based upon satellite imagery of the region. [46] The estimates assume two crops per year per hectare in Colombia.[47] Mexico's poppy crop grows in three seasons, each of which is estimated separately. (Note that because satellite imagery for much of Colombia was unavailable due to poor weather conditions in 2005, the calculated average of 2004 and 2006 estimates is used as an estimate of 2005 cultivation for each growing region.)
Opium Gum Yield	Poppy crops under cultivation are translated into **opium yield**, measured as **oven-dried opium gum**. For example, in Northern Mexico a hectare of poppy yields about 22.6 kilograms of dried opium gum; in Southern Mexico the yield is about 18.7 kilograms.[48] New yield estimates for Colombia specify different yields for different growing areas. A hectare of poppy yields between 13.9 and 24.6 kilograms of dried opium gum. U.S. government agencies have conducted several opium yield studies in cooperation with host nations: CNC in Mexico (2000-2002) and DEA in Colombia. Researchers sampled 1-meter plots from a representative and accessible selection of fields. In Colombia, researchers then measured the height, diameter, and opium yield of at least 10 lanced mature capsules from each plot (refer to Appendix A1 for technical details). In Mexico, researchers measured each mature capsule in each square-meter plot. The estimates derived from these studies were consistent with previous poppy yield estimates from Thailand and Pakistan. In order to project the eventual total yield from a plot, the researchers also counted the number of mature capsules, immature capsules, flowers, flower buds, and stalks with missing capsules from each plot. Expectations were that the missing capsules had been harvested and that the immature capsules, flowers, and flower buds would be harvested. Given the yield estimates and the composition of the sampled fields, the researchers were able to project the eventual yield from a typical plot. In combination with farmer interviews, this methodology provides a tool for relatively quickly estimating opium poppy yields and other variables in remote, often dangerous, growing areas. This estimation methodology forms the basis for the heroin availability estimates.

46 Nariño represents a new growing area, first surveyed in 2004.

47 This information is based upon research conducted by DEA. That research showed two crops per year in all growing areas except Nariño, which had one crop per year.

48 Whenever stated, yield is per annum rather than per crop. Two or more crops may be harvested on a single hectare in any given year.

Table 3.4. Description of Factors used to Estimate Heroin Potential Production by CNC

Factor	***Description***
Production Efficiency	DEA completed 35 simulation studies of the production of morphine base from latex and another 12 simulation studies of the production of heroin HCl from morphine base. Taken together, the results from these simulation studies provide estimates of **production efficiency**. For example, during 2006 in Colombia, 37 metric tons of dried opium gum yielded 4.6 metric tons of pure heroin; during 2005 in Mexico, 71 metric tons of dried opium gum yielded 8.3 metric tons of pure heroin.[49] *Note. The formulation is different for Colombia (where there have been special studies) and Mexico (where such studies have not been completed). For Colombia, the factors required to convert a metric ton of dried opium gum into heroin are described below. These calculations yield an estimate of 0.125 kilograms of heroin per kilograms of opium gum harvested, or a ratio of 8 to 1. To be specific, "opium latex" is a term used only for Colombian production. In Mexico, where opium is collected as opium gum, a similar factor converts opium gum production to oven-dried opium yield. According to CNC potential production estimates, 8.5 grams of opium gum are required to obtain 1 gram of heroin HCl. Thus, the conversion rate of dried opium gum to heroin is (1/8.5) or 0.1176.*
Weight Conversion	This factor represents the **weight conversion** needed to transform the weight of dried opium gum into a wet latex equivalent. (When multiplied by crop yield, opium yield (described above) provided estimates of *dried* opium gum. The DEA studies of production efficiency are based on *wet* yield, so another factor must be introduced to convert dry yield into wet yield.) Special DEA studies found that the average moisture content of latex is around 65 to 70 percent. Thus, the calculations apply a factor of 3 to convert dried opium to wet latex.
Morphine Content	According to DEA, the average **morphine content for the wet latex** is 4.45 percent by weight. That is, 1 gram of wet latex contains 0.0445 grams of morphine.
Morphine Extraction Efficiency	According to DEA laboratory studies, the average **efficiency of extracting the morphine** from the latex is about 79.2 percent by weight. That is, the production process extracts 0.792 grams of morphine per 1 gram of morphine contained in the latex.
Morphine to HCl Conversion Efficiency	DEA testing found that the average **efficiency of converting morphine to heroin HCl** is 84.7 percent. This means that the second step of the production extracts 0.847 gram equivalents of morphine in the form of heroin from 1 gram of morphine.
Molecular Weight Conversion	The **molecular weight conversion** is necessary to account for the fact that the chemical conversion from the base (morphine) into the salt (heroin) causes a molecule of heroin to be heavier than a molecule of morphine. A 1-gram equivalent of morphine translates into 1.397 grams of heroin.

49 The basis of these calculations can be inferred from DEA research reports and CNC slideshow presentations provided to the Drug Availability Interagency Working Group.

Estimating Heroin Potential Production for 2006: An Illustration

Table 3.5 provides details for estimating the potential production of pure and export quality (EQ)[50] heroin in both Colombia and Mexico in 2006, the first step in deriving a supply-based estimate. The table shows the hectares under cultivation in Colombia and Mexico, the opium gum yield from those hectares, and the resulting total pure heroin yield. For example 2,340 hectares of poppy were under cultivation in Colombia during 2006. These hectares yielded 4.6 metric tons of pure heroin. In Mexico, 5,100 hectares were under cultivation during 2006 and yielded 12.6 metric tons of pure heroin. Therefore, the potential amount of pure heroin produced in the Western Hemisphere is estimated to be 17.6 metric tons. Table 3.5 illustrates the calculations that lie behind the estimates previously reported in Table 3.1.

[50] Heroin is never refined to 100 percent purity levels: "export quality" refers to the purity of heroin that is shipped out of the producing country. This will vary from country to country and year to year based upon local practices.

Table 3.5. 2006 Heroin Potential Production in the Western Hemisphere

Factor	*Growing region*	*Area of poppy cult*	*Opium gum yield*	*Gum-to-latex weight conversion*	*Morphine alkaloid content*	*Morphine extraction efficiency*	*Heroin HCl processing efficiency*	*Molecular weight conversion*	*Potential pure heroin$_{WH}$*
Unit of measurement	Region name	Ha	MT/ha/yr	Weight of wet latex/dried gum equivalent	Alkaloid/ latex	Morphine base/ alkaloid	Heroin HCl/ morphine base	Molecular weight of HCl/base	MT
Colombia	Peraguas	0	0.0139	3	0.0445	0.792	0.847	1.397	0.0
	Cauca	408	0.0139	3	0.0445	0.792	0.847	1.397	0.7
	Huila	498	0.0153	3	0.0445	0.792	0.847	1.397	1.0
	North Tolima	194	0.0131	3	0.0445	0.792	0.847	1.397	0.3
	South Tolima	202	0.0139	3	0.0445	0.792	0.847	1.397	0.4
	Tolima	422	0.0127	3	0.0445	0.792	0.847	1.397	0.7
	Perijá	412	0.0184	3	0.0445	0.792	0.847	1.397	0.9
	Urama	0	0.0139	3	0.0445	0.792	0.847	1.397	0.0
	Nariño	204	0.0246	3	0.0445	0.792	0.847	1.397	0.6
	Total	2,340							4.6
Mexico	Northern	3,790	0.0226	3			0.0281	1.397	10.1
	Southern	1,310	0.0187	3			0.0281	1.397	2.9
	Total	5,100							13.0
Western Hemisphere (WH)	Total	7,438							17.6

3.2.2 Estimating the Amount of Pure Heroin Available to U.S. Markets from the Western Hemisphere after Source Area Consumption and Losses

The second step in the estimation of the availability of heroin to the United States ***subtracts losses and source area consumption from the potential heroin produced in Colombia and Mexico*** to obtain the amount of heroin available to U.S. markets from the Western Hemisphere. Losses are defined as **seizures** in the source country (i.e., Colombia and Mexico) and the United States. Within Colombia and Mexico, seizures of both export quality heroin and a much smaller amount of raw opium (converted to export quality weights) are included.[51] The methodology for U.S. seizures uses Heroin Signature Program (HSP) data to estimate the proportion of seized heroin that comes from Colombia and Mexico.[52] The calculations prorate those estimated proportions across all the heroin seizures captured in the Federal-wide Drug Seizure System (FDSS) data. More details on the derivation of seizure estimates are provided in Appendix A2.

Using the FDSS data, the bulk total amount of heroin that is seized was calculated for each year from 2001 to 2006. This amount was apportioned between Mexico and Colombia using analysis of the HSP data (see Appendix A2 for a full description of the methods for producing these proportions). Since seizures are reported in export quality weights, the estimation methodology converts the seizures into a **pure heroin equivalent** separately for Colombia and Mexico.

Source area consumption is also subtracted from the potential production to calculate the availability of pure heroin. CNC estimates that non-U.S. users consume approximately 1 to 2 metric tons of heroin annually.[53] The source area consumption estimate used here is the average (1.5 metric tons per each year) of that range.

The resulting estimates of heroin available to U.S. markets from Mexico and Colombia are presented later in this section in Table 3.8.

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51 These data are gathered from the supplementary tables to the U.N. World Drug Reports, Seizures, 2000–2005, Opium (raw and prepared) and Seizures, 2000–2005, Heroin. Data for 2006 is based on a 3-year average of data from 2003 through 2005.

52 The HSP provides heroin signature information for arrival zone heroin seizures in DEA's STRIDE data set. Source areas are identified as South America (Colombia), Mexico, Southeast Asia, and Southwest Asia. The DEA's HSP provides the best available and only scientifically based data on heroin smuggled into the United States. Nonetheless, the HSP is not intended to provide U.S. market shares for each of the heroin source areas in any given year. Moreover, fluctuations from year to year in the proportion from each source area may reflect shifting law enforcement priorities, significant seizures, and changing trafficking patterns. Rather, data from the HSP are used in conjunction with investigative intelligence and with drug potential production and seizure data to develop an overall, long-term assessment of the trafficking of heroin into and within the United States.

53 These estimates are based upon information provided by CNC at the Drug Availability Interagency Working Group meeting on December 11, 2007. Canadian consumption is not included here because much of the available heroin in Canada originates in Asia.

3.2.3 Estimating the Proportion of Heroin Consumed in the United States that Comes from the Western Hemisphere

The final step calculates the amount of heroin available in the United States from all source areas as a multiple of heroin from the Western Hemisphere; that is, the quantity of heroin supplied to the United States from the Western Hemisphere (estimates derived from the first two steps described in 3.2.1 and 3.2.2 above) is divided by the ***proportion of heroin consumed by the United States from the Western Hemisphere***.

Estimates of the proportion of heroin consumed in the United States that comes from the Western Hemisphere are based principally on Heroin Domestic Monitor Program (HDMP) data over the period of 2000 through 2006.[54] Only records for retail-level purchases (defined as a purchase price of at most $200) with a known source area (i.e., Mexico, South America, Southeast Asia, or Southwest Asia) are included in the analysis. These purchases are distributed over 20 metropolitan statistical areas (MSAs), as well as 38 other locations that were grouped to form the "rest of United States." Hereafter MSAs will be referred to as *cities* according to convention.

The HDMP has a fixed size sample within each city, so a simple tabulation of HDMP purchases would over-represent cities where heroin use is relatively rare and under-represent cities with a large heroin use problem.[55] To adjust for this, the proportion of drug-related emergency room visits (as reported to DAWN *Live!*) was used as a surrogate indicator of the relative level of heroin use in each city.[56] That is, the city-year proportions were weighted by the DAWN *Live!* data.[57]

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54 Although most of the purchases came from the HDMP, a few were purchases from the HSP. A critical discussion of the HDMP can be found elsewhere (Rhodes et al., 1998). For this analysis, all STRIDE observations present in drug categories 904 and 905 were selected. Observations in category 904 correspond to the HSP while observations in category 905 correspond to the HDMP for heroin. As noted in the text, to be included in the analysis, an observation had to be a retail-level purchase, defined as a purchase with price of $200 or less. Excluded from these observations were observations prior to 2000, those without a U.S. state designation, and airport seizures, which were assumed to be international.

55 The HDMP provides some geographic weighting via the number of quarterly purchases in each site. In 21 of the 28 participating cities, 10 purchases per quarter are required. In New York, however, 20 purchases per quarter are required, whereas only 5 purchases per quarter are required in the remaining 6 cities: Minneapolis, El Paso, San Antonio, Pittsburgh, Portland (OR), and Richmond (VA). Thus, the greatest number of retail purchases are made in New York to reflect its status as the most significant heroin user market, and fewer purchases are made in the smaller user markets in the 6 cities noted.

56 SAMHSA administers the DAWN *Live*! program, which provides real-time drug-related emergency room data for select cities throughout the United States. The analysis used DAWN data to develop a single weight that was constant across time.

57 These data were merged with weights derived using the DAWN *Live!* data set. The weights refer to the proportion of emergency department visits in each examined MSA. The weights were assigned to the specific MSA if it was present in the data set. Otherwise, the MSA was given an average weight corresponding to emergency department visits in the rest of the United States. Frequencies were then computed for each of the years from 2000 to 2006 for the heroin signatures across the MSAs. The observations for these frequencies were weighted using the DAWN *Live!* data as mentioned previously.

Weighting is approximate but served to provide larger weights to cities that are associated with a relatively large number of heroin users. As would be expected, New York received the largest weight (0.11) followed by Chicago (0.10), Baltimore (0.06) and Philadelphia (0.05). Cities such as Minneapolis, Dallas and Houston received weights that were less than 0.01.[58]

Table 3.6 shows the resulting estimated distribution of heroin consumed in the United States across the four source areas between 2001 and 2006. The table illustrates the relatively high proportion of heroin from Mexico and South America and, consequently, the relatively low proportion from other sources, specifically Southeast and Southwest Asia.

Table 3.6. Estimated Origin of Heroin Consumed in the United States: 2000–2006

Year	*Mexico*	*South America*	*Southeast Asia*	*Southwest Asia*	*Total*
2000	25.3%	68.2%	1.0%	5.5%	100.0%
2001	33.9%	61.0%	0.7%	4.4%	100.0%
2002	31.0%	64.6%	1.4%	2.9%	100.0%
2003	37.1%	59.3%	0.2%	3.5%	100.0%
2004	52.5%	45.5%	0.8%	1.2%	100.0%
2005	45.4%	50.4%	0.2%	4.0%	100.0%
2006	53.2%	46.1%	0.0%	0.7%	100.0%

Source: Calculations performed by Abt Associates using data from the Heroin Domestic Monitor Program, the Heroin Signature Program and DAWN Live.

The amount of heroin available to the United States can be calculated by estimating the potential supply from the two dominant sources—South America and Mexico—and representing that figure as a proportion of the total amount available. For example, in 2006, approximately 99 percent of the heroin consumed in the United States was supplied by Mexico (53.2 percent) and South America (46.1 percent), as shown in Table 3.6. Thus, using the estimated quantities supplied by those two source areas, it is possible to estimate the remaining portion (less than 1 percent) from other sources areas.

This method can be applied in three different ways. First, the total available heroin from Colombia and Mexico can be divided by the proportion of heroin in the United States from the Western Hemisphere (method 1). This is the preferred method because it only requires an accurate accounting of the proportion of heroin used in the United States that comes from the Western Hemisphere.

Method 2 and method 3 provide sensitivity checks. The heroin available from the two source areas can be calculated separately for South America (method 2) and Mexico (method 3) and then scaled up to represent the total amount of heroin available to the United States. After accounting for sampling

58 One might have used the DAWN weights differently. For example, the weights might have been based on the number of emergency room mentions that were for detoxification because these admissions are most likely for heavy use. The weights would not change much, however. Taking the average between 2004 and 2009 (from the DAWN Live! site) New York would receive a weight of 0.17, Chicago would receive a weight of 0.11 and Minneapolis, Dallas and Houston would continue to receive very low weights.

variation, if the availability and source data are accurate, these three methods should produce the same result. However, this is not the case, as shown in Table 3.7.

Table 3.7. Differences in Production Potential Based on the Three Methodologies (Metric Tons)

Method & Region	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*
Method 1: MX & SA	12	21	13	18	11	11	16
Method 2: SA	10	16	10	10	5	5	7
Method 3: MX	17	31	21	32	16	18	24

The following illustration applies 2006 data (i.e., estimated production and losses) to the three methods described above to highlight the disparate results. For example, if the 3.1 metric tons of heroin available from Colombia truly represents only 46 percent of the market, then the amount of available heroin in the United States would be expected to be approximately 7 metric tons. (That is, 3.1 divided by 46 percent yields 6.7 metric tons of total heroin available.) However, if the 12.6 metric tons coming from Mexico truly represents 53 percent of the market, then available heroin would be expected to be closer to 24 metric tons (12.6 divided by 53 percent yields 23.8 metric tons of total heroin available).[59] Calculating the two source areas combined and calculating the share of the market they supply to be 99 percent, yields an expected availability of 16 metric tons (12.6 divided by 99 percent yields 16.2 metric tons of total heroin available). The individual figures for Mexico and Colombia can be found later in the section in Table 3.8.

The discrepancies in the results produced by the three different methods stem from one of two factors: unaccounted supplies in South America (thus yielding artificially low estimates) or higher than actual estimates of the proportion of heroin coming from South America. The Drug Availability Interagency Working Group uniformly supported the first possibility as more likely, given the unexplained dramatic drop in heroin potential production as measured by analysis of satellite photography. However, as suggested earlier, one cannot discount the possibility that the DHMP data underestimate the true proportion of heroin coming from Mexico. This could happen if Mexican producers have increasingly switched to using production processes used in Colombia.

The following estimation uses method 1. However, if the Drug Availability Interagency working group is correct, this method will understate production because it understates Colombian potential production. Method 3 might be preferable, but it has the disadvantage that it requires an accurate partitioning of U.S. consumption attributed to Mexico and South America.

3.2.4 The Availability of Pure Heroin in the United States

Table 3.8 shows the resulting estimates of availability of heroin in the United States based on the three steps described above (Sections 3.2.1–3.2.3). The table combines *production* and *seizure data* to yield the amount of heroin available for U.S. markets. Seizures in the source country and in the United States are first converted from export quality volumes to pure volumes and then subtracted from the potential production figures for that country. *Non-U.S. consumption* is subtracted from this value to calculate the amount of pure heroin available to U.S. markets. Finally, the amount available to U.S. markets from the

[59] This estimate does not adjust for the roughly 1.5 metric tons used in Mexico.

Western Hemisphere is divided by the *proportion of heroin consumed by the United States* from the Western Hemisphere to estimate the metric tons of pure heroin available to the United States from all sources (the Western Hemisphere, Southeast Asia and Southwest Asia).

For example, during 2006, Colombia produced 4.6 metric tons of pure heroin. About 2.0 metric tons of export quality heroin were seized. Given that export quality heroin was about 70 percent pure, seizures removed 1.4 metric tons of pure heroin. The remaining 3.1 metric tons was available to U.S. markets.

Together Colombia and Mexico provided 15.8 metric tons—3.1 metric tons from Colombia and 12.6 metric tons from Mexico (numbers differ slightly due to rounding)—of pure heroin to the United States in 2006, after accounting for losses/seizures.[60] Subtracting non-U.S. consumption from this value yields 14.3 metric tons destined for the United States. Using the multiplier based on the proportion of heroin consumed by the United States, Colombia and Mexico accounted for 99 percent of U.S. heroin consumption, so the total amount of heroin from all sources was 14.4 pure metric tons. This discussion explains the derivation of the estimates reported in table 3.3.

[60] To calculate quantities of pure heroin, the amount of export quality heroin was multiplied by the purity of export quality heroin. The reason for converting from pure heroin to export quality heroin and then back to pure heroin is that seizures are reported as export quality amounts.

Table 3.8: Heroin Supply-side Estimates and Calculations for 2001–2006 in Metric Tons

Country	Step	Growing Area	2001	2002	2003	2004	2005	2006
Colombia	Hectares of poppy cultivated	Peraguas	200	160	373	211	*No growing area estimates due to cloud cover.	0
		Cauca	450	490	662	182		408
		Huila	800	590	618	281		498
		North Tolima	250	560	284	125		194
		South Tolima	1,180	970	838	376		202
		Tolima	2,060	1,230	668	548		422
		Perijá	800	220	570	275		412
		Urama	700	680	325	100		0
		Nariño				17		204
		Total Ha Cultivated	**6,440**	**4,900**	**4,338**	**2,115**	**2,228**	**2,340**
	Opium prod.	Opium gum (MT)	91.6	68.0	62.7	30.3	31.0	36.6
		Total pure heroin	**11.4**	**8.5**	**7.8**	**3.8**	**3.9**	**4.6**
	Subtract from supply	Losses (EQ)	2.17	2.93	2.67	2.21	1.92	2.04
		EQ purity	79.3%	79.0%	75.8%	78.3%	68.4%	70.2%
		Losses (pure)	1.7	2.3	2.0	1.7	1.3	1.4
		Available for U.S. markets (pure)	**9.7**	**6.2**	**5.8**	**2.1**	**2.6**	**3.1**
Mexico	Poppy Cult. (Ha)	Northern	2,200	1,900	3,000	2,000	2,300	3,790
		Southern	2,200	800	1,800	1,500	1,000	1,310
		Total Ha Cultivated	**4,400**	**2,700**	**4,800**	**3,500**	**3,300**	**5,100**
	Opium prod.	Opium gum (MT)	90.9	57.9	101.5	73.3	70.7	110.2
		Total pure heroin	**10.7**	**6.8**	**11.9**	**8.6**	**8.3**	**13.0**
	Subtract from supply	Losses (EQ)	1.01	0.56	0.38	0.61	0.70	0.83
		EQ purity	16.7%	29.3%	40.4%	25.1%	40.2%	39.1%
		Losses (pure)	0.2	0.2	0.2	0.2	0.3	0.3
		Available for U.S. markets (pure)	**10.5**	**6.6**	**11.8**	**8.5**	**8.0**	**12.6**
Heroin Available in U.S.	Potential production of pure heroin in Western Hemisphere (MT)		20.25	12.83	17.60	10.52	10.59	15.78
	Total non-U.S. consumption		1.5	1.5	1.5	1.5	1.5	1.5
	Percentage of heroin in U.S. from Western Hemisphere		94.9%	95.7%	96.3%	98.0%	95.8%	99.4%
	Pure heroin in U.S. (MT)		**19.8**	**11.8**	**16.7**	**9.2**	**9.5**	**14.4**

3.3 Comparison of Heroin Availability Estimates to Other Sources

According to available estimates, there has been a striking drop in opium potential production in Colombia. CNC cultivation estimates for Colombia show a drop of nearly two-thirds, from 6,440 hectares in 2001 to 2,340 hectares in 2006. Although this may be true, sources have expressed concern that Colombian potential production has been underestimated in recent years. That surmise is consistent with the observation that about 22 percent of the Colombian potential production was removed between 2001 and 2003 while about 36 percent was removed between 2003 and 2006. If anti-drug technology had remained about constant over that period, the trend toward higher loss rates could be attributed to underreporting of Colombian potential production.

Mexican potential production estimates also decreased between 2001 and 2005, though they then recovered to 5,100 hectares in 2006. Taking into account the seizures in source countries and in the United States, the estimates show a long-term constancy in the availability of heroin. To support or contradict these estimates, one can review production estimates from other sources, estimates of consumption figures, and statistics regarding trends in drug purity and prices.

3.3.1 Other Potential Production Estimates

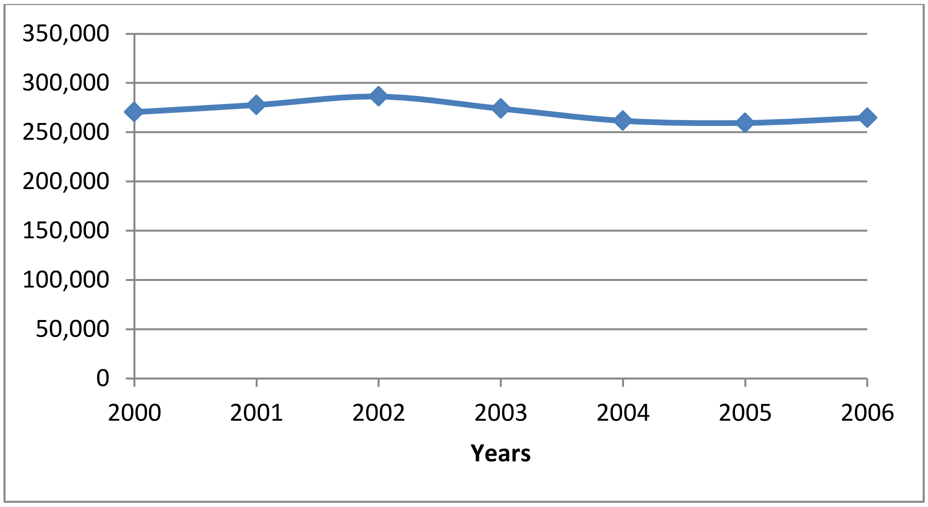
The estimates of opium production presented in Table 3.8 agree broadly with the estimates provided by the Colombian government to UNODC for the years 2001 through 2003: 15 percent higher than Colombian government estimates in 2001, 11 percent lower in 2002, and 17 percent lower in 2003. However, in 2004, the estimates presented in this report are only 54 percent of the Colombian government estimates. If there were confidence in the Colombian government estimates, one could take this as evidence that the 2004 crop potential production estimates were too small. Such an assertion seems unwarranted, however, because the estimates presented in this report are actually 261 percent higher than the Colombian government estimates for 2006. Consequently, the Colombian government estimates do not provide confirmation.

3.3.2 Trends in Treatment Admissions

While this model has no direct measure of the number of heroin users in the United States, Treatment Episode Data Set (TEDS) shown in Figure 3.1) do provide the numbers of admissions among people seeking heroin-related treatment from publicly funded facilities. While TEDS cannot estimate the total number of users, it can provide evidence of trends. Using the most recent data available, treatment episodes peaked in 2002[61] and fell each year by 10,000 to 12,000 admissions. Although a decrease in the availability of heroin may have contributed to this decrease in treatment admissions, the TEDS data show only a modest decrease (11 percent).

[61] This is consistent with CNC estimates of potential heroin production, which peaked in 2001. Because some time will lapse between shortages in heroin supply and users seeking treatment, it is reasonable that the corresponding peak seen in the TEDS data occurs in 2002.

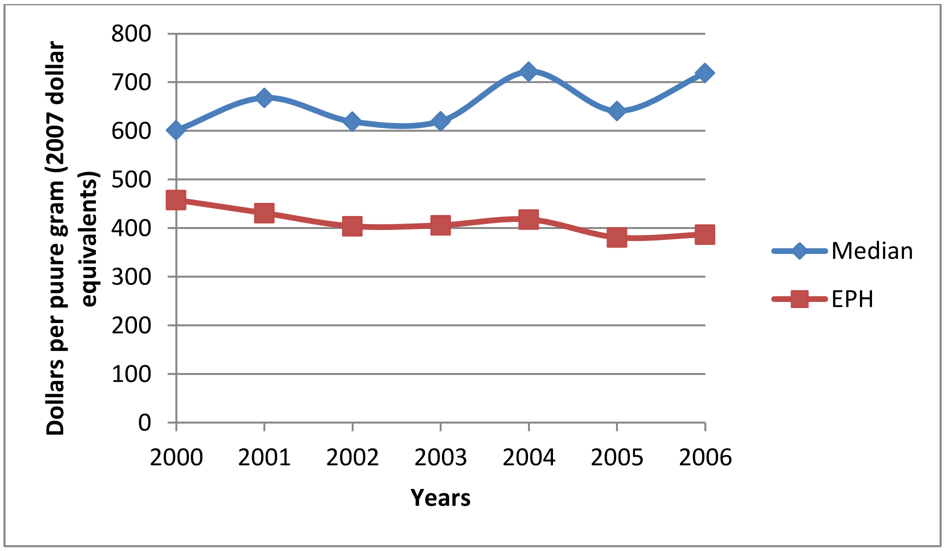
Figure 3.1. Heroin-Related Treatment Admissions



3.3.3 Price Trends

Another source of information to support or refute the evidence of decreased supply is drug pricing. Assuming that demand is constant, a shortage of heroin should cause price per pure gram to increase; a surplus of heroin should cause price per pure gram to decrease. Analyzing data from the System to Retrieve Information from Drug Evidence, Fries and his colleagues (2008, Table B-13, p. B-33) make a compelling case that heroin prices have remained constant during most of the period of interest here.

Figure 3.2. Heroin-Related Treatment Admissions



The figure shows two estimates for retail prices, defined as price paid per pure gram purchased for purchases between 0.1 and 1 pure gram. The first is the median price paid for all purchases that fell within the criterion category of 0.1 to 1 pure grams. The second is based on the expected purity hypothesis (EPH). Estimates based on the expected purity hypothesis show no trend; estimates based on medians may show an upward trend, but the change is not large.

3.3.4 Demand-Based Estimates

There is value in comparing estimates of heroin availability with demand-based estimates. The most recent demand-based estimates, from *What America's Users Spend on Illegal Drugs* (ONDCP, 2011) suggest that heroin users consumed nearly 30 metric tons of heroin per year. The supply-based estimated were closer to 15 metric tons.

The supply-based and demand-based estimates differ in scale but are consistent with respect to trend. When considering scale, however, the reader should be aware that the demand-based estimates have a standard error of about 5 metric tons. As reported earlier, the supply-based estimates have a standard error close to 5 metric tons and this report has expressed concern that the supply-based estimates may be too small because of underestimation of Colombian potential production. Therefore the differences in scale between the supply-based and demand-based estimates may be smaller than implied by this table.

3.4 Conclusions

The supply-based data suggest that the heroin market in the United States has been affected by the decreases in potential production in both Colombia and Mexico. However, the implied decrease in heroin use in the United States is not on the same scale as the decrease in production. The HDMP data continues to show that the vast majority (95 to 99 percent) of heroin comes from South America and Mexico, so the gap between demand and supply is perplexing.

The first possible explanation is that there has been a change in the mode of potential production. CNC data may underestimate the amount of heroin being produced in Colombia. This may be the case if the Colombian producers are growing opium poppy in more remote areas or mixed with other crops, or using other methods to hide their opium production more effectively than in previous years. There is no direct evidence of this, but it would explain in part the deficit between the known supply and the consumption of heroin.

In addition, there may be other sources within South America producing heroin that reaches the United States. There is some evidence that small amounts of opium may have begun to be grown in Peru with the raw opium to be processed into heroin being shipped in the neighboring countries of Ecuador and Colombia. Guatemala has historically also been a source of opium poppy cultivation. However, neither of these sources has yet been determined to be of sizable quantities.

Chapter 4: Availability of Methamphetamine

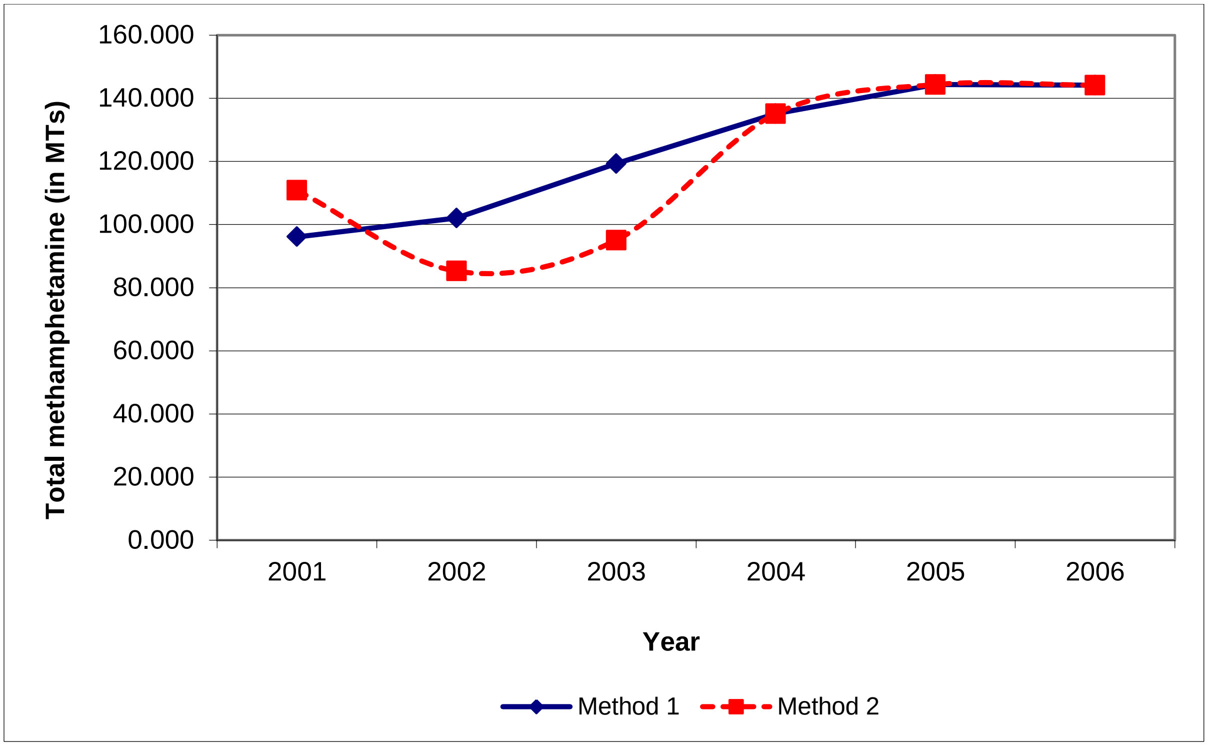
4.1 Summary

During the time period studied—2001 through 2006—the methamphetamine available for consumption in the United States was both produced in the United States and imported as finished product, predominantly from Mexico. In addition to multiple sources, differences in precursor availability necessitated the use of various methods of methamphetamine production. Thus, in contrast to the relatively straightforward calculations used to estimate the availability of drugs such as cocaine and heroin, estimating methamphetamine availability requires more complex calculations. These calculations estimate methamphetamine supplied to the U.S. market by the following three steps: 1) production of methamphetamine by small toxic labs (STLs) using over-the-counter (OTC) products containing ephedrine or pseudoephedrine (EPH/PSE); 2) production of methamphetamine by domestic super labs (DSLs) using diverted bulk EPH/PSE from the U.S. and Canadian pharmaceutical industry; and, 3) importation of methamphetamine produced outside the United States (mainly Mexico) and smuggled into the United States as finished product.

In the following section, a single approach is used to calculate the amount of methamphetamine produced by STLs (step 1) and DSLs (step 2): estimated diverted supplies of EPH/PSE products and bulk EPH/PSE are converted to finished product and seizures are subtracted from that quantity. Two separate methods are then employed to estimate the supply of methamphetamine imported as finished product from Mexico (step 3). In the first method, imported methamphetamine is estimated for an anchor year (2004) and then workplace drug testing data are used to develop a non-linear consumption path. From this, domestic production is subtracted and the residual is considered to have been imported. In the second method, imported methamphetamine is estimated using precursor supply statistics to calculate total imported finished product. This second method is applied only to the earlier years of the period studied (2001 through 2003) because reliable information is lacking for 2005 and 2006.

As Figure 4.1 shows, these two methods produce different results for 2001 through 2003: 2001 (96.1 metric tons for method 1 compared with 110.8 metric tons for method 2), 2002 (102.0 metric tons compared with 85.2 metric tons), and 2003 (119.2 metric tons compared with 95.0 metric tons). In the later years of the period studied, the two methods necessarily yield the same results: 135.1 metric tons in 2004, 144.3 metric tons in 2005, and 144.1 metric tons in 2006. The supply of methamphetamine from STLs and DSLs declined from 2001 through 2006, likely in response to restrictions on both precursor imports and law enforcement focus on laboratory seizures. Meanwhile supplies of foreign imports of finished product increased, presumably to meet consumer demand.

Figure 4.1. Availability of Methamphetamine: Estimates from Two Methods



The subsequent sections provide details on the derivation of the estimates. The estimation methodology and estimates are described in ***Section 4.2***. To evaluate the reliability of the estimates, ***Section 4.3*** compares the estimates from Section 4.2 against other drug use measures. Concluding remarks are provided in ***Section 4.4***.

4.2 Methodology

Unlike heroin, cocaine, and marijuana, which are derived from plant materials, methamphetamine is produced both in the United States and abroad from precursor chemicals, currently most often EPH and PSE. EPH/PSE commonly come in bulk form and are common ingredients in many OTC and prescription respiratory ailment remedies. Thus, manufacturers of cold medications import large quantities of EPH/PSE in bulk form each year to produce legitimate pharmaceuticals. Clandestine laboratories then divert bulk EPH/PSE from the legitimate market, purchase illicit EPH/PSE, or extract EPH/PSE from OTC products to produce methamphetamine.[62]

Given the sensitivity of nations to the problem of illicit methamphetamine manufacture from EPH/PSE, the Combat Methamphetamine Epidemic Act of 2005 required that the International Narcotics Control Strategy Report (INCSR) provide a list of the top five world exporters and importers of these substances. It also required the United States to review legitimate demand for the chemicals and develop quotas for

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[62] The methodology excludes methamphetamine produced using phenyl-2-propanone (P2P). P2P has been a tightly controlled substance for decades, although clandestine laboratories can manufacture it from phenylacetic acid. However, accessing EPH/PSE has until recently been easier, as is the synthesis process using these precursors, than using the P2P-based method.

these chemicals in an effort to remove market excess of EPH/PSE that could potentially be diverted to clandestine laboratories. The U.N. Commission on Narcotic Drugs in Resolution 49/3 in 2006 requested countries to provide their estimates of legitimate demand to the U.N. International Narcotics Control Board (INCB) (U.S. Department of State, 2007).

The methodology for estimating domestic methamphetamine availability outlined in the ensuing subsections identifies three steps through which methamphetamine enters the U.S. market:

1) Production of methamphetamine by STLs from legally manufactured OTC products (e.g., tablets, gel caps, inhalers, syrups) containing EPH/PSE.

The source of EPH/PSE supplies for the STLs that produce small quantities of methamphetamine has traditionally been the OTC respiratory remedies in multi-count bottles, blister packs, inhalant devices or syrups sold in pharmacies, convenience stores and large discount houses.[63] This source, seriously restricted by state and Federal regulations beginning in 2003, produces a lower yield or poorer quality methamphetamine and involves additional production steps than methamphetamine made directly from EPH/PSE.

2) Production of methamphetamine by DSLs from bulk EPH/PSE that is legally imported and intended for use for pharmaceutical needs, but is diverted to clandestine labs for conversion to methamphetamine.

DSLs are the most likely to use this source of EPH/PSE supplies.[64] Whether the bulk supplies are diverted once they have arrived in the United States or are transported directly from foreign sources, bulk EPH/PSE provides the most efficient and highest quality product for manufacture of methamphetamine on a large scale. During the early part of the period of interest, EPH/PSE was easily acquired from Canada, and the working assumption is that Canada provided all the necessary EPH/PSE required by DSLs.

3) Finished product methamphetamine manufactured outside the United States and smuggled into the United States.

With increasing pressure on all domestic laboratories combined with tightened restrictions on EPH/PSE in the United States, the third channel of methamphetamine—product manufactured *outside* the United States and moved into the market as finished methamphetamine—became increasingly important. Precursor materials used in the foreign manufacture of methamphetamine come from either excess legal imports of precursor material or illegal imports of precursor materials into the producing country where it is converted into methamphetamine. Some portion of that finished product is seized and some

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63 This methodology assumes that the STLs are the primary users of precursor materials derived from OTC medications. This assumption is based on descriptions in DEA Threat Assessments that detail the contents of small laboratory seizures. However, prior to the implementation of tighter restrictions, both STL and DSL operators also may have used mail order suppliers of EPH/PSE tablets.

64 DSLs are defined as laboratories within the United States that are capable of producing 10 or more pounds of methamphetamine in a production cycle.

is consumed in the producing country; the remainder is available to be exported. Foreign production facilities are predominately located in Mexico.

The individual components of each step are discussed in the following sections: *subsection 4.2.1* details the methodology and estimates for the availability of methamphetamine from STL production, the first step; *subsection 4.2.2* provides details on the second step—the estimation of the supply of methamphetamine from DSLs; step 3 (the supply estimates from foreign sources) is detailed in *subsection 4.2.3*; and *subsection 4.2.4* provides the final availability estimates derived from these three steps.

4.2.1 Supply of Methamphetamine from Small Toxic Labs (STLs)

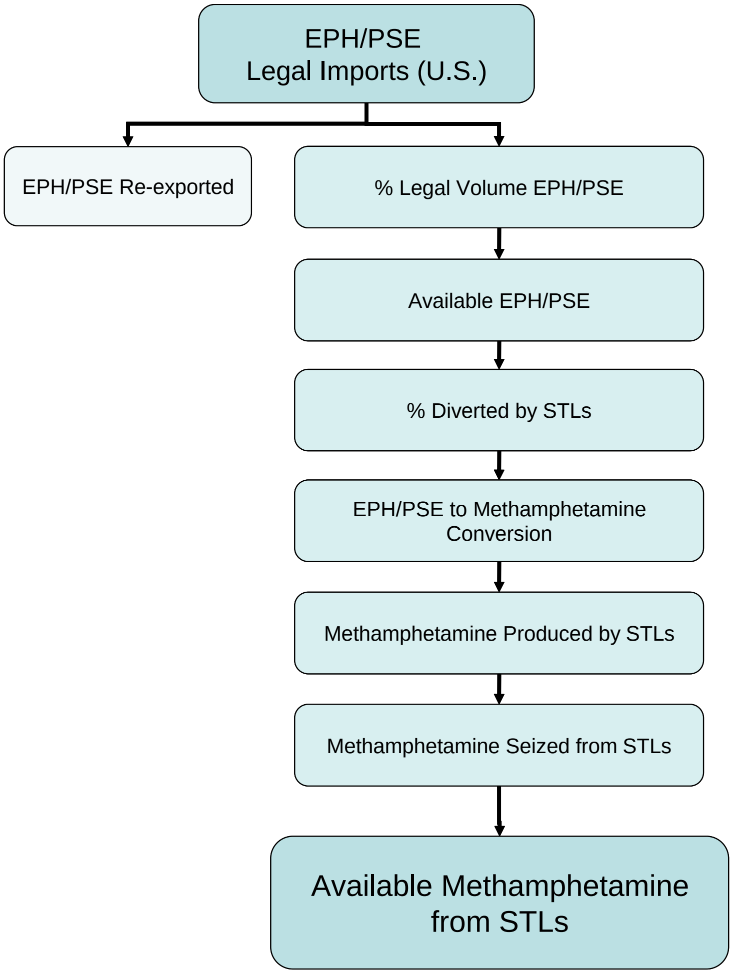
To calculate the methamphetamine supply available via the first step—methamphetamine produced by STLs—first an estimate is calculated for an anchor year. In this case, 2005 is used because there are sufficient data on legal production of OTC EPH/PSE products (such as cold tablets, inhalers, and other respiratory medications) for that year derived from a DEA-sponsored study that estimates legal utilization in the United States (IMS Health, 2006).[65] Second, from the 2005 estimate, an estimate of the total available methamphetamine produced domestically by STLs for the other years (2001 through 2004 and 2006) is calculated using trends in the seizures of STLs. These two steps are detailed below.

2005 Supply Estimate based on Illegal Use of Legitimate EPH/PSE Products

As illustrated in Exhibit 4.1 below, the 2005 estimate is derived by determining the amount of OTC products containing EPH/PSE that are diverted by STLs for the production of methamphetamine, applying a conversion rate, and subtracting the amount of methamphetamine produced by STLs that is seized domestically.

[65] In this calculation, the EPH/PSE that went into the production of prescription medications is not included as a potential source of STL methamphetamine, as this is an unlikely channel for accumulation of the amount of precursor needed to produce methamphetamine. It is assumed that the source of precursors for illegal use from legally produced supplies comes via the OTC market.

Exhibit 4.1. Estimating Domestic Production of Methamphetamine by Small Toxic Labs



The estimate of methamphetamine produced by STLs (illustrated in Exhibit 4.1) is derived from the factors detailed in Table 4.1 below.

Table 4.1. Description of Factors used to Estimate the Supply of Methamphetamine from STLs

Factor	***Description***
EPH/PSE Legal Imports (U.S.)	This factor represents the total weight of EPH/PSE imported legally into the United States from all world partners reporting to the COMTRADE database. The U.N. reports that in 2005, 186,996 kilograms of ephedrine and 407,440 kilograms of pseudoephedrine were imported into the United States for a total of 594,436 kilograms of precursor materials (COMTRADE, 2007).
EPH/PSE Re-exported	The amount of EPH/PSE re-exported by the United States (47,224 kilograms in 2005) to all world partners is subtracted from EPH/PSE imported legally into the United States to get the total amount of legitimate precursors available for legal production of EPH/PSE products by the U.S. pharmaceutical industry (COMTRADE, 2007).

Table 4.1. Description of Factors used to Estimate the Supply of Methamphetamine from STLs

Factor	*Description*
% Legal Volume EPH/PSE[66]	The estimated percentage (85%) of legally imported EPH/PSE used for legal production is derived from the 2006 study commissioned by DEA to determine industry utilization for EPH/PSE in 2005. The report found that 85 percent of the total PSE imported was used in legal production of pharmaceuticals. The proportion of the total EPH imported that was estimated as used in legitimate production (3,800 kilograms) was a far lower proportion (3%) but may not have adequately covered all legitimate channels of production.[67] In the absence of a more comprehensive estimate of legal use of EPH, this methodology assumes the same utilization rate for both EPH/PSE (85% of the total imports).
Available EPH/PSE	The percentage of legally imported EPH/PSE is multiplied by the amount of precursors available (EPH/PSE legally imported *minus* EPH/PSE re-exported) to calculate the total amount of EPH/PSE used in legitimate production in the United States (465,130 kilograms in 2005).
% Diverted by STLs	The estimated percentage (5%) of OTC EPH/PSE products that are diverted by STLs to be used in the production of methamphetamine.[68] The percentage of diverted EPH/PSE is multiplied by the estimated amount of OTC derived EPH/PSE available for legal use and provides an estimate of 23,257 kilograms in 2005 of EPH/PSE diverted by STLs.
EPH/PSE to Methamphetamine Conversion	This factor represents the rate for converting OTC products to EPH/PSE to methamphetamine by STLs. This methodology applies a 55 percent conversion rate.[69]
Methamphetamine Produced by STLs	The total amount of methamphetamine produced by STLs is determined by multiplying the percent of EPH/PSE diverted by STLs by the methamphetamine conversion rate.

66 The methodology assumes that the remainder could potentially be diverted by DSLs for the production of methamphetamine.

67 In Testimony before the Committee on the Judiciary on July 12,2007, E. Heiden, representing the American Council for Regulatory Compliance, an association of manufacturers, importers and distributors of ephedrine based OTC medications, argued that the IMS Health estimates missed over 27 metric tons of product utilized by the convenience store, small independent grocery, and online mail order market. Many products from this source are not scanned at sale or are contained in products such as vitamin supplements, veterinary products or other merchandise not defined within the scope of the IMS study (Heiden, 2007).

68 There is no estimate available regarding the proportion of the medication and OTC market that is purchased or diverted for use in methamphetamine production. For purposes of this estimate, this methodology assumes 5 percent. Although this estimate is crude, the proportion of production by STLs is likely a small and declining proportion of methamphetamine production.

69 STLs can range considerably in their equipment and skill of the “cook,” producing widely varying yields. This methodology applies an average 55 percent conversion rate, consistent with the recommendation of the Drug Availability Interagency Working Group participants from the DEA.

Table 4.1. Description of Factors used to Estimate the Supply of Methamphetamine from STLs

Factor	*Description*
Meth Seized from STLs	The last factor represents seizures in the United States of STL-produced methamphetamine, as reported in FDSS.[70] FDSS does not distinguish the type or size of the laboratory, so estimates are inexact. Seizures of pure methamphetamine weighing less than 4.5 kilograms (approximately 10 pounds) that were not seized by U.S. Immigration and Customs Enforcement (ICE) were treated as STL seizures. Using this assumption, in 2005, 850 kilograms of STL-produced methamphetamine were seized in the United States. The amount seized is then subtracted to obtain **the estimate of the total methamphetamine available in the United States in 2005 that is produced by STLs.**

Table 4.2 shows the calculations of each of these factors for 2005. Using this methodology, **the estimated total amount of methamphetamine available from STLs** in 2005 is approximately 11.94 metric tons.

Table 4.2. STL Production in 2005 (Kilograms)

Factors	*Estimate*
EPH/PSE legal imports (U.S.)	594,436
Ephedrine	186,996
Pseudoephedrine	407,440
EPH/PSE re-exported	47,224
Ephedrine	5,272
Pseudoephedrine	41,952
% legal volume EPH/PSE[71]	85 %
Available EPH/PSE	465,130
% diverted by STLs	5.0 %
Illegal use by STLs	23,257
EPH/PSE to methamphetamine conversion	55 %
Methamphetamine produced by STLs (pure)	12,791
Meth seized from STLs (pure)	850
Total pure meth available in U.S. from STLs	11,941

Projected Estimates for Other Years Based on Seizures of STLs (2001 through 2004 and 2006)

In order to estimate methamphetamine produced by STLs in the other years (2001 through 2004 and 2006), the methodology assumes that the number of STLs operating in any given year is proportional to the number of STLs seized during that year. For example, if the **number of STLs seized doubled** from

70 The purity of seizures reported in FDSS was imputed according to an algorithm, the details of which can be found in Appendix B1.

71 The methodology assumes that the remainder could potentially be diverted by DSLs for the production of methamphetamine.

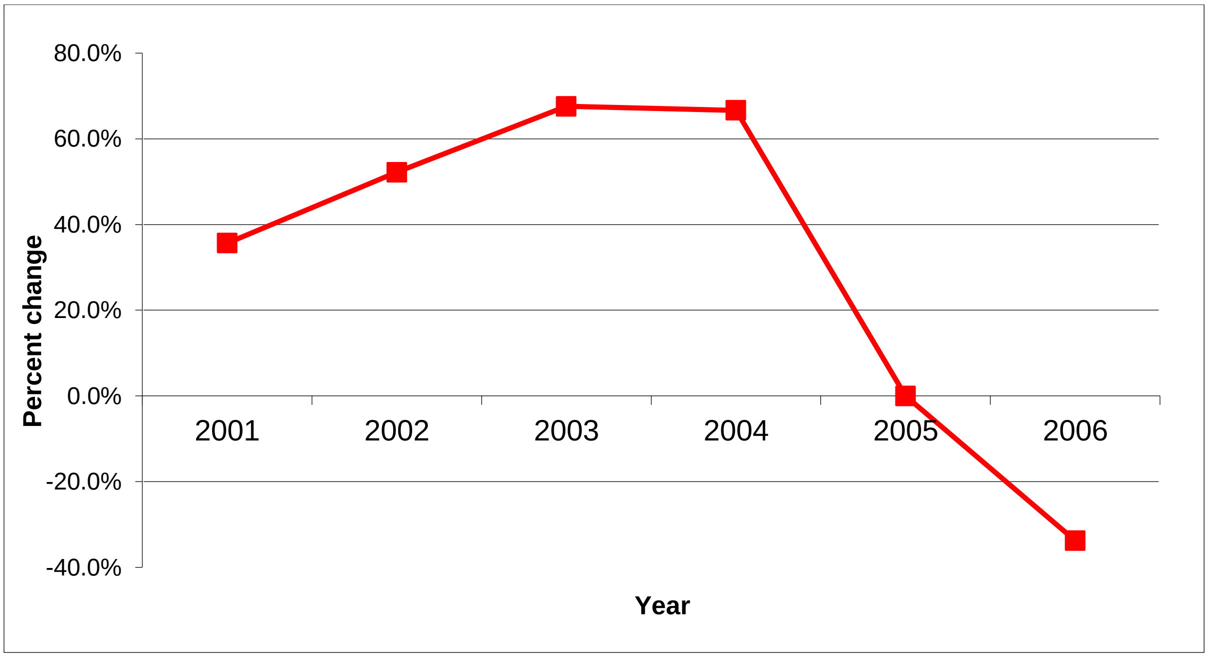
one year to the next, then the best estimate is that **supply has also doubled.**[72] **Table 4.3** shows the number of STLs seized in 2001 through 2006.[73]

Table 4.3. STL Seizures (2001–2006)

	2001	2002	2003	2004	2005	2006
Number of STLs seized	8,106	9,094	10,013	9,959	5,976	3,959

Figure 4.2 depicts the percent change in STLs relative to 2005, and Figure 4.3 depicts the estimate of available methamphetamine calculated using the 2005 reference point. Overall, the trends are generally supported by how the market appears to have changed in this time span. Prior to first state and then Federal restrictions on both imports and the sale of OTC medications containing EPH/PSE, STLs proliferated. With increasing restrictions, their numbers appear to have dropped.

Figure 4.2. Percent Change in Total STLs relative to 2005



[72] Specifically, let L_i = the total number of STLs seized in year i, for $i \neq 2005$

L_{2005} = the total number of STLs seized in 2005,

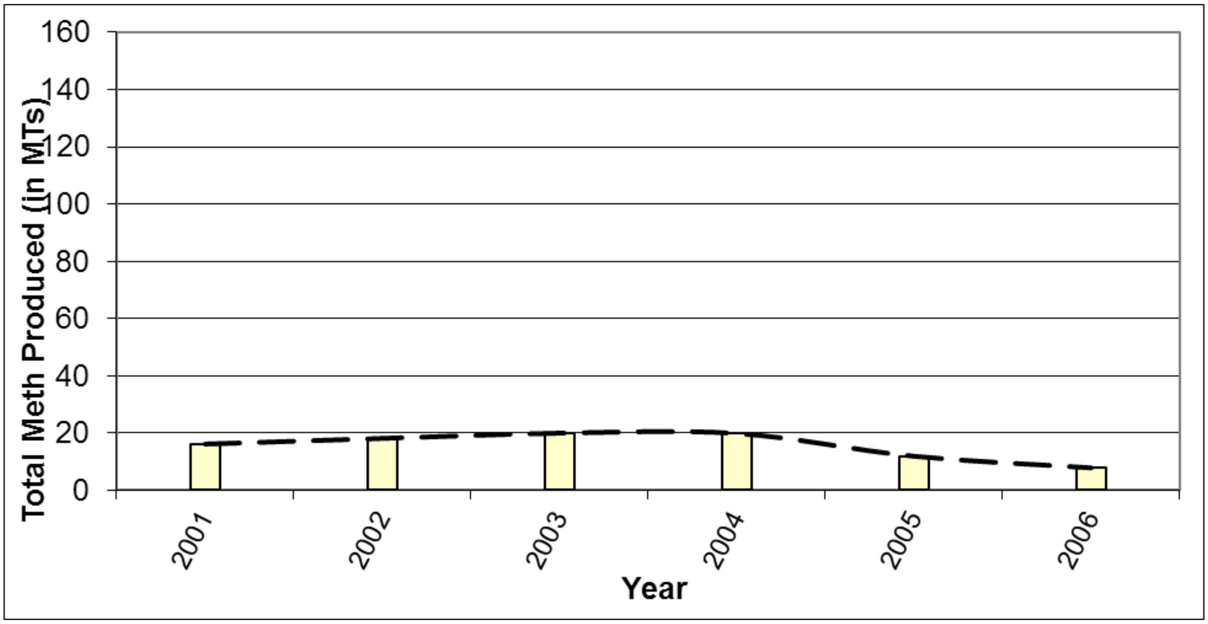
and A_i = the total amount of methamphetamine available in year i,

A_{2005} = the estimated amount of methamphetamine available in 2005,

such that, $A_i = (L_i/L_{2005})^* A_{2005}$

[73] These data were extracted on February 26, 2011 from the National Seizure System (NSS), El Paso Intelligence Center (EPIC).

Figure 4.3. Availability Estimates of STL-produced Methamphetamine, Based on STL Seizures



4.2.2 Supply of Methamphetamine from Domestic Super Labs (DSLs)

The second step—methamphetamine produced by domestic DSLs—is calculated using estimates of EPH/PSE diverted from legitimate industry use in the United States as well as estimates of EPH/PSE illegally imported from Canada into the United States. An estimate is calculated first for 2001 because sufficient data exist regarding imports of EPH/PSE and legal utilization for both Canada and the United States for this year. An estimate of the total available methamphetamine produced by DSLs for the other years (2002 through 2006) is then derived using trends in the seizures of DSLs. The following sections detail these two steps and the resulting estimates.

2001 Supply Estimate based on Diverted Legitimate U.S. and Canadian Imports of PSE/EPH

Exhibit 4.2 below depicts the flow of precursors in generating domestically produced methamphetamine by DSLs. To summarize, the 2001 estimate is derived by determining the amount of EPH/PSE illegally diverted from legitimate industry use for the production of methamphetamine by DSLs, applying a conversion rate, and subtracting the amount of methamphetamine seized in the United States that was produced by DSLs.

The methamphetamine manufactured by DSLs in 2001 was produced using EPH/PSE diverted from legitimate industry use in the United States and EPH/PSE illegally imported from Canada into the United States.[74] The potential diversion of legal EPH/PSE is estimated to be the amount of precursor imported that is in excess of the legitimate industry use. This calculation does not include what could not be observed, i.e., EPH/PSE illegally imported into Canada.[75]

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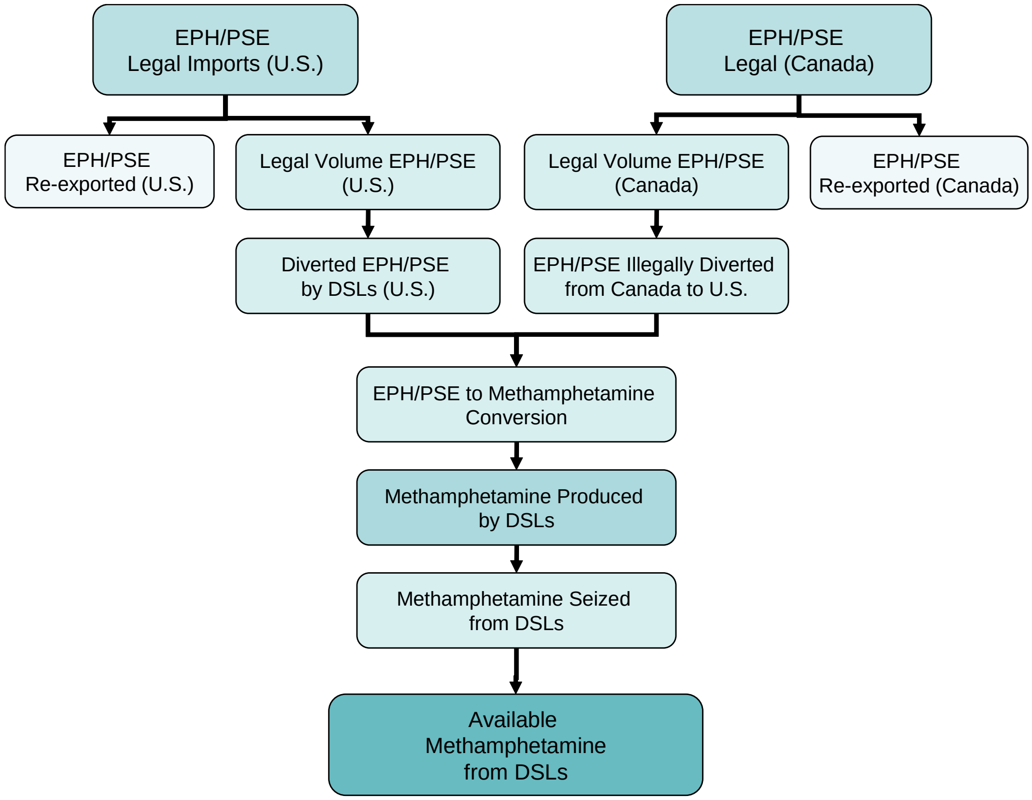
[74] The methodology assumes that in 2001, Canadian traffickers diverted excess legal precursor to the United States as EPH/PSE, not as finished product methamphetamine.

[75] Legal imports likely comprised total imports because there were few restrictions on imported EPH/PSE during 2001. Thereafter imports were increasingly restricted, so the legitimate supply was unlikely to account for all imports. For this reason, 2001 is used as an anchor year.

Exhibit 4.2. Estimating Domestic Production of Methamphetamine by Domestic Super Labs



The estimate of the supply of methamphetamine produced by DSLs is derived from the factors detailed in Table 4.4 below, which are cross-referenced to Exhibit 4.2.

Table 4.4. Description of Factors used to Estimate the Supply of Methamphetamine from DSLs

Factor	*Description*
EPH/PSE Legal Imports (U.S.)	As defined previously (in Table 4.1), this factor represents the total EPH/PSE imported legally into the United States from all world trading partners. In 2001, 298,273 kilograms of ephedrine and 736,164 kilograms of pseudoephedrine were imported into the United States for a total of 1,034,437 kilograms of precursor materials.
EPH/PSE Re-exported (U.S.)	As defined in Table 4.1, this is the amount of EPH/PSE re-exported by the United States (107,686 kilograms in 2001).
Legal Volume EPH/PSE (U.S.)[76]	This factor represents the total amount of legally imported EPH/PSE that is used in the legal production of EPH/PSE by the pharmaceutical industry in the United States. In 2001, 884,000 kilograms of EPH/PSE was used in the legitimate production of EPH/PSE products in the United States.[77]

76 This estimate was derived from data provided by the Consumer Healthcare Product Association (CHPA) at the request of DEA. CHPA represents approximately 90 percent of PSE legitimate industry use. Estimates for legitimate use of EPH were derived from data provided to the Drug Availability interagency working group by three primary 2001 pharmaceutical producers: Bayer, Whitehall-Robbins, and Novus Fine Chemicals.

77 Ibid.

Table 4.4. Description of Factors used to Estimate the Supply of Methamphetamine from DSLs

Factor	*Description*
Diverted EPH/PSE by DSLs (U.S.)	The legal volume EPH/PSE and re-exported EPH/PSE is subtracted from the total amount of imported EPH/PSE to obtain the total amount of EPH/PSE that could potentially be diverted by DSLs. This leaves 42,751 kilograms of EPH/PSE as potentially available to be diverted by DSLs.
EPH/PSE Legal (Canada)	This factor represents the total EPH/PSE imported legally into Canada. COMTRADE (2007) reports that in 2001, 4,742 kilograms of ephedrine and 105,811 kilograms of pseudoephedrine were imported into Canada for a total of 110,553 kilograms of precursor materials.
EPH/PSE Re-exported (Canada)	This factor is the amount of EPH/PSE re-exported by Canada (38 kilograms in 2001 as reported by COMTRADE, 2007).
Legal Volume EPH/PSE (Canada)	This factor represents the total amount of legally imported EPH/PSE that is used in the legal production of EPH/PSE products in Canada. An estimated 33,800 kilograms of EPH/PSE were used in the legitimate production of EPH/PSE products in Canada in 2001 (COMTRADE, 2007).
EPH/PSE Illegally Diverted from Canada to the United States	The potential amount of EPH/PSE illegally diverted to the United States is estimated to be the amount of precursor imported that is in excess of the legitimate industry use in Canada. That is, it is calculated by subtracting the amount of EPH/PSE re-exported by Canada and the amount of EPH/PSE that is used in the legal production in Canada from the total EPH/PSE imported legally into Canada. Thus, an estimated 76,715 kilograms of EPH/PSE from Canada were potentially available to be diverted by DSLs.
EPH/PSE to Methamphetamine Conversion/ Methamphetamine Produced by DSLs	A conversion rate of 70 percent is applied to the U.S. and Canadian estimates of precursors available for production by DSLs (42.8 and 76.7 metric tons, respectively) to determine the likely *amount of methamphetamine produced by DSLs* from these two sources of EPH/PSE.[78]
Methamphetamine Seized from DSLs	The total amount of DSL-produced methamphetamine seized in 2001 as reported by EPIC. About 10,360 kilograms of pure methamphetamine were seized within the United States in 2001. The amount seized is deducted from DSL production to obtain **an estimate of the total methamphetamine available in the United States that is produced by DSLs in 2001.**

Table 4.5 shows the calculations of each of these factors for 2001. Using this methodology, **the estimated total amount of methamphetamine available from DSLs** in 2001 is approximately 73.3 metric tons. As shown in Table 4.5 below, the 2001 estimate aggregates DSL production of pure methamphetamine from precursors in Canada and the United States (83.6 MTs) so that methamphetamine seized from DSLs can be subtracted from the production numbers (since seizure data do not differentiate between seizures of methamphetamine that were produced from Canadian precursors and methamphetamine produced from U.S. precursors).

[78] As is true with STLs, the conversion rate for DSLs varies by the size of the operation and sophistication of both the illicit chemist and his/her equipment. This methodology assumes a 70 percent conversion for DSLs based on a literature review and guidance provided by DEA participants in the Drug Availability Interagency Working Group.

Table 4.5. DSL Production in 2001 (Kilograms)

Factors	*United States*	*Canada*
EPH/PSE legal imports	1,034,437	110,553
Ephedrine	298,273	4,742
Pseudoephedrine	736,164	105,811
EPH/PSE re-exported	107,686	38
Ephedrine	1,085	0
Pseudoephedrine	106,601	38
Legal volume EPH/PSE	884,000	33,800
Diverted for illegal use by DSLs[79]	42,751	76,715
	United States and Canada[80]	
EPH/PSE to methamphetamine conversion	70%	
Methamphetamine produced by DSLs (pure)	83,626	
Meth seized from DSLs (pure)	10,360	
Total pure meth available in U.S. from DSLs	73,266	

Projected Estimates for Other Years (2002–2006) Based on Seizures of DSLs

In estimating methamphetamine availability by DSLs, the same procedure used for estimating supply from STLs is applied. That is, changes in large clandestine laboratory seizures are used to estimate the trend in supply over time (Table 4.6 shows the number of DSL seizures for each year).[81] However, rather than relying on the 2005 production information from the precursor methodology (since, as discussed previously, there is less confidence in the DSL estimate in that year), the 2001 estimate (73.3 metric tons) is used as the reference point.

Table 4.6. DSL Seizures: 2001–2006

	2001	*2002*	*2003*	*2004*	*2005*	*2006*
Number of DSLs seized	246	144	130	54	34	18

Figure 4.4 below shows the application of the aforementioned method to DSLs and is cumulative with Figure 4.3. The figure shows the estimated amount of methamphetamine produced from DSLs, subtracting seizures for the United States and Canada. These separate estimates for the United States and Canada were calculated from the proportion of EPH/PSE that was diverted for illegal use in the United States and Canada in 2001 and 2005. In 2001, 36 percent of EPH/PSE diverted for illegal use was from the United States, and 64 percent was from Canada. This proportion was applied to the 2001 availability estimate of 73.3 MTs to obtain the division of available methamphetamine between Canada and the United States (i.e., 47.1 metric tons and 26.2 metric tons of methamphetamine was made from

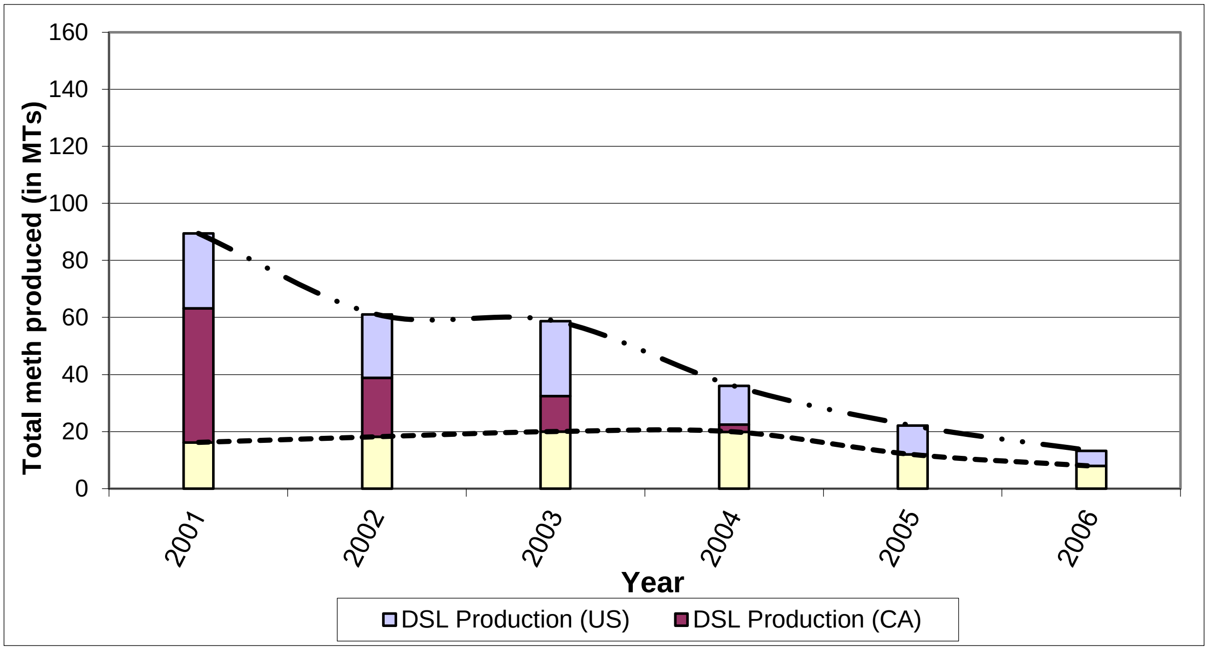
79 One hundred percent of precursor imported that is in excess of the legitimate industry use is assumed to be diverted for illegal use by DSLs.

80 The differences between the U.S. and Canada lie in the proportion of available precursor that is legitimately used—95 percent of U.S. imported precursor material versus 31 percent of Canadian imported precursor. Using these estimates of availability of "extra" material, the amount available for diversion to DSLs from Canadian sources versus U.S. sources is almost double. For the conversion of EPH/PSE to methamphetamine and the amount of pure methamphetamine seized from DSLs, we assume that all material from both sources is diverted to DSL production and is available to the U.S. market.

81 These data were extracted on February 26, 2011 from the National Seizure System (NSS), El Paso Intelligence Center (EPIC).

precursor originating from Canada and the United States, respectively). As shown in Figure 4.4, none of the excess EPH/PSE in 2005 originated from Canada, implying that all DSL production came from U.S. precursor. To estimate the division of methamphetamine produced from U.S. and Canadian precursors in the other years (i.e., 2002–2004 and 2006), we constructed a simple linear trend of the proportion of excess EPH/PSE from each of the source countries over time, using the 2001 and 2005 proportions (i.e., 36 percent U.S. and 64 percent Canadian in 2001 and 100 percent U.S. in 2005) as reference points.

Figure 4.4. DSL Production: Projected Estimates Based on DSL Seizures



4.2.3 Foreign Production of Methamphetamine

Finally, the third step—the total methamphetamine produced in Mexico[82] and imported as finished product—is calculated using 2004 as an anchor year. The total amount of methamphetamine available from Mexico in 2004 (approximately 99 metric tons) is then used to estimate the supply from 2001 through 2003 and 2005 through 2006 using two methods.

The first method uses Quest workplace drug testing data to provide an estimate of the change in production needed to meet consumption from year to year. Known STL and DSL production is then subtracted from the total production estimate to get a residual amount that represents the amount of methamphetamine imported as finished product each year. Figure 4.5 (below) shows the application of this approach to derive estimates of imported methamphetamine from Mexico for each year.

82 The focus is on Mexico as the source of finished product because of both the inordinately large amount of excess precursor available for diversion in that country each year until 2006 and the evidence of Southwest border seizures. Data from ICE indicate increasing methamphetamine seizures from Mexico in 2002 to 2006, lending support to this assumption. Canada, on the other hand, shows dramatic *decreases* in legal imports of precursor—from over 50 metric tons in 2002 and 2003 to less than half that amount from 2005 forward. Assuming a consistent or declining pharmaceutical industry use (estimated at 33 metric tons in 2001), there is likely little or nothing available for diversion from legitimate precursor supplies.

The second method used to estimate total methamphetamine produced in Mexico and imported as finished product relies upon imports reported to the U.N. Commodity Trade Statistics Database (COMTRADE) each year. This provides an estimate of total imported finished product, which is applied to the calculation for every year, excluding 2005 and 2006 for which reliable information is lacking. Figure 4.6 shows the application of the second approach to derive estimates of imported methamphetamine for 2001 through 2003.

2004 Estimate Based on Production of Methamphetamine in Mexico

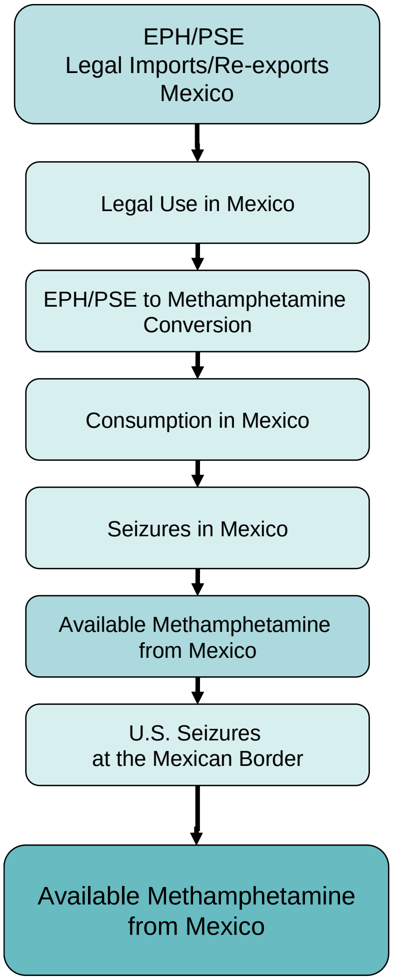
Exhibit 4.3 illustrates the estimation methodology for 2004. It estimates the amount of foreign-produced methamphetamine produced in Mexico minus the amount seized and/or consumed in that country that is then transported to the United States as finished product. Finally, the available methamphetamine to the United States from Mexico is calculated by subtracting seizures by the United States at the Mexican border.

The 2004 estimate is used for two reasons:

1) This is the year in which Mexican imports of precursor material reached a peak at 227 metric tons of EPH/PSE. The methodology assumes that all excess available precursor was converted into methamphetamine and exported to the United States and was enough to meet the demands of the U.S. market (not already filled by DSLs and STLs).

2) 2004 is considered to be a reliable year for data because the Mexican government had not yet begun limiting the legal importation of EPH/PSE. In other words, the Mexican methamphetamine industry was unlikely to require a large black market for precursors during 2004. Thereafter, restrictions on imports of EPH/PSE likely resulted in an increase in illegal import of EPH/PSE, but since these are not recorded in international trade statistics, they could not be factored into availability estimates after 2004.

Exhibit 4.3. Estimating Foreign Production of Methamphetamine



The estimate of foreign methamphetamine available for consumption in the United States is derived from the factors detailed in Table 4.7, which are cross-referenced in Exhibit 4.3.

Table 4.7. Description of Factors used to Estimate the Supply of Methamphetamine from Mexico

Factor	Description
EPH/PSE Legal Imports/Re-exports Mexico	This factor is the amount of EPH/PSE that is imported into Mexico minus the amount of EPH/PSE re-exported by Mexico as reported by COMTRADE. In 2004, 226,718 kilograms of EPH/PSE were available in Mexico.
Legal Use in Mexico	The legal use of EPH/PSE in Mexico is based on an estimate provided by the Mexican government in response to requests from the U.S. Department of State (2007). The Mexican government estimated that 70,000 kilograms of EPH/PSE were used in the legitimate production of EPH/PSE products in Mexico in 2004. This amount is subtracted from the amount of EPH/PSE that is legally available in Mexico (i.e., the amount imported minus the amount re-exported) to calculate the amount of precursor available for meth production.
EPH/PSE to Methamphetamine Conversion	A conversion rate (70%) is applied to determine the potential amount of methamphetamine produced in Mexico.

Table 4.7. Description of Factors used to Estimate the Supply of Methamphetamine from Mexico

Factor	Description
Consumption in Mexico	This factor represents the estimated consumption of methamphetamine in Mexico in 2004. Mexican government reports estimated between 5 to 10 metric tons of methamphetamine consumption annually from 2002 through 2003. Here, the average (7.5 metric tons) is used as the Mexican consumption estimate.
Seizures in Mexico	In 2004, 952 kilograms of methamphetamine were seized in Mexico (UNODC, 2007).
Available Methamphetamine from Mexico	Mexican consumption and seizures of methamphetamine are subtracted from the potential amount of methamphetamine produced in Mexico to calculate the potential amount of methamphetamine available to the United States from Mexico.
U.S. Seizures at the Mexican Border	The total amount of pure methamphetamine seized at all ports of entry at all U.S. borders is reported by ICE.[83] In 2004, 2,135 kilograms of pure methamphetamine were seized at all U.S. borders. The amount seized at the U.S. border is then subtracted to obtain the estimate of **the total amount of methamphetamine available in the United States in 2004 that is produced by foreign sources**.

Using this methodology, **the total amount of methamphetamine available from Mexico** is estimated to be approximately 99 metric tons during 2004. The calculations used to derive this estimate are provided in Table 4.8.

Table 4.8. Foreign (Mexico) Production in 2004 (Kilograms)

Factors	*Estimate*
EPH/PSE legal imports/exports Mexico	226,718
Legal use in Mexico	70,000
Available precursor	156,718
EPH/PSE to methamphetamine conversion	70 %
Methamphetamine produced in Mexico	109,703
Consumption in Mexico	7,500
Seizures in Mexico	952
Available methamphetamine from Mexico	101,251
U.S. seizures at Mexican border	2,135
Total pure meth available in U.S. from Mexico	99,116

Projected Estimates for Other Years (2002 through 2006) Based on Two Alternative Methods

An estimate of the total methamphetamine that is illegally imported and domestically available for each year is derived using two methods.

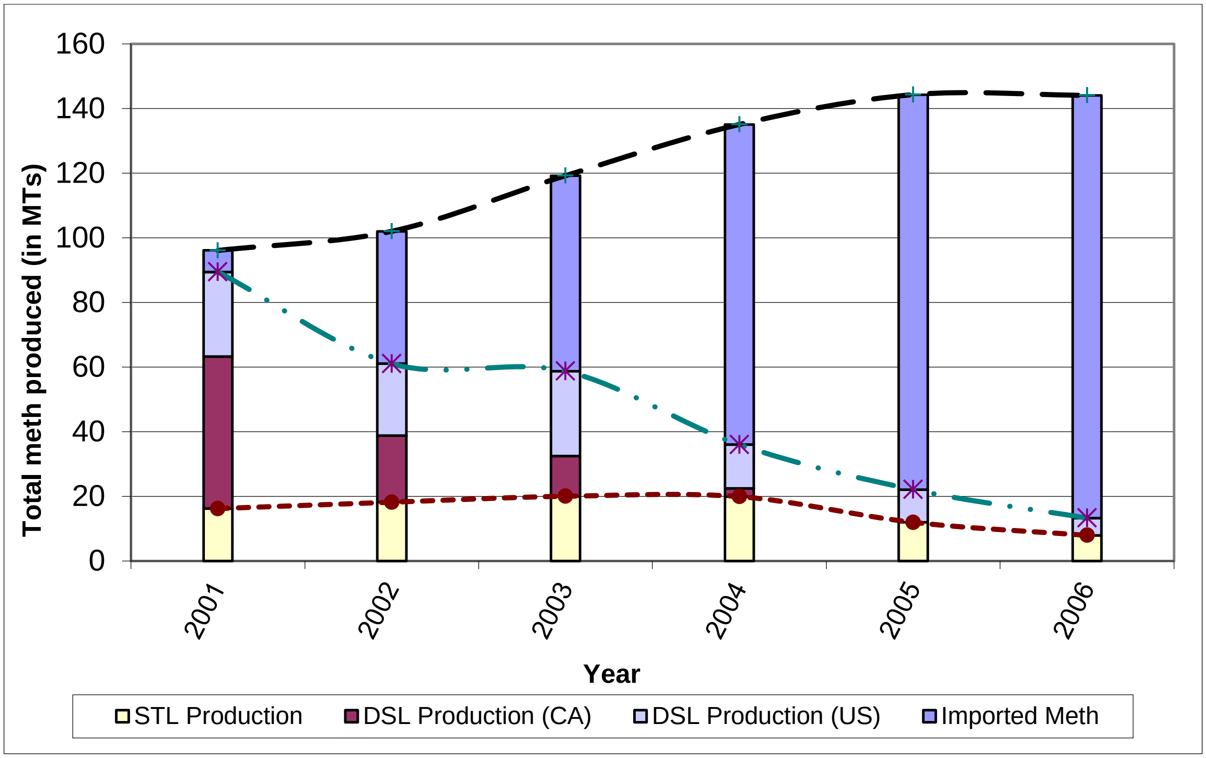
For method 1, the sum of 2004 production elements (i.e., STLs, DSLs, and foreign sources) is used as the best estimate of total production of imported methamphetamine in that year. Next, using 2004 as a reference point, a nonlinear consumption path is derived using Quest workplace drug testing data to provide an estimate of the change in production from year to year.[84] Finally, known STL and DSL

83 Because the amount of methamphetamine seized at the border can fluctuate randomly over time, a smoothed, linear trend line is used to predict the amount of pure methamphetamine seized for 2004. First, linear regression was estimated for the amount of pure methamphetamine seized from 2001 through 2006. Then using this estimation, the amount seized in 2004 was predicted.

84 This trend and its derivation are described in greater detail in Appendix B2. Quest workplace drug testing data are used as an indicator of a segment of the general population (U.S. workforce) usage that is gauged by a

production is subtracted from the total production estimate to get a residual amount that represents the amount of methamphetamine imported as finished product each year. Figure 4.5 shows the application of this approach to deriving estimates of imported methamphetamine from Mexico for each year. Note that Figure 4.5 is cumulative with Figure 4.4.

Figure 4.5. Supply of Methamphetamine Calculated Using Method #1: Total Amount from Consumption Path



The second method (method 2) employed to estimate the amount of imported methamphetamine starts with the actual COMTRADE numbers (as in Table 4.8) for each year. This provides an estimate of total imported finished product, which is applied to the calculation for every year, excluding 2005 and 2006 for which reliable information for the factors used to calculate foreign production is lacking. As mentioned above, because the Mexican government imposed no rigorous controls on EPH/PSE before 2005, the methodology assumes that legitimate imports likely represent *all* EPH/PSE imports. That is, when legal imports were unrestricted, there was little need to smuggle in illegal source materials. With a tightening of import regulations in 2005, however, manufacturers of methamphetamine would have been forced to purchase from illegal sources. Hence, it is possible to observe excess imports through 2004, but not illegal imports from 2005 and 2006. For these two years, the methodology applies the estimates from method 1. Figure 4.6 shows the application of method 2 to derive estimates of imported methamphetamine. As with the previous figure, Figure 4.6 is cumulative with Figure 4.4. The top line in Figure 4.6 reproduces the cumulative line from method 1 as drawn in Figure 4.5.

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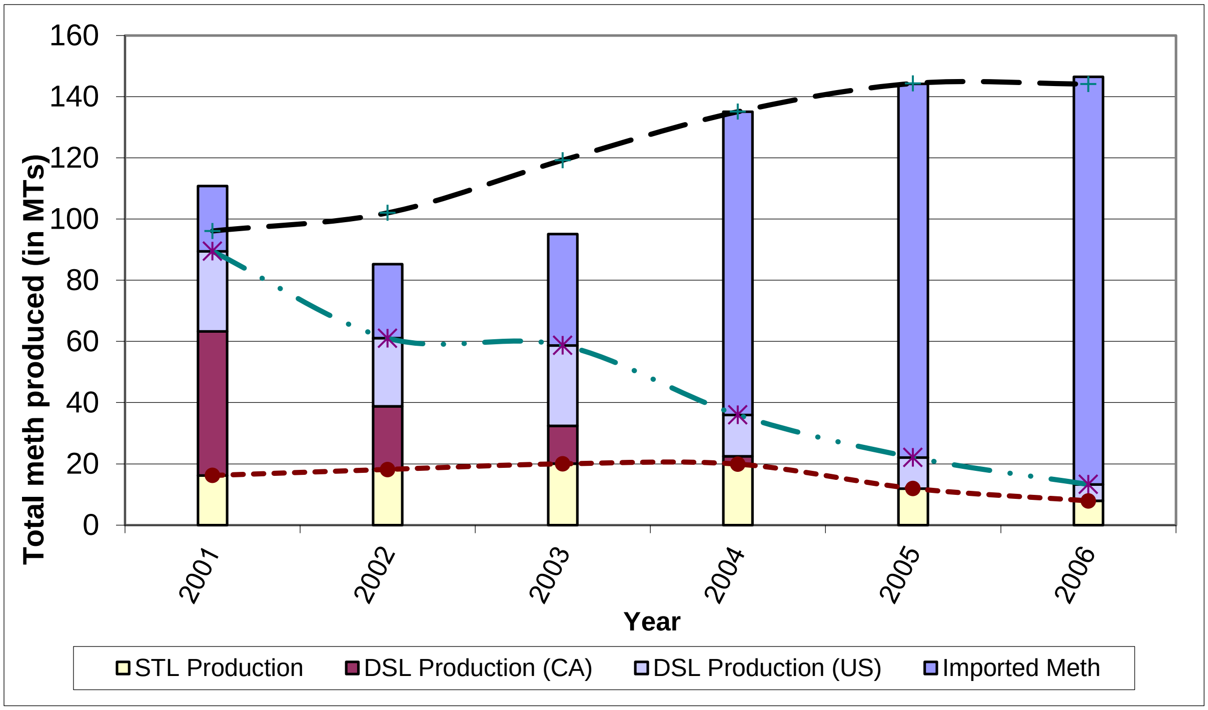
bioassay rather than self-reported data in other general population sources like the NSDUH. Quest Diagnostics provides laboratory test services for testing drug use for a variety of private and public sector employers who contract for this service. Data are reported for two types of drug tests: random and pre-employment tests. The trends used in the estimates are based on both subsets.

Figure 4.6. Supply of Methamphetamine Calculated Using Method (2): Total Amount from EPH/PSE Imported to Mexico



4.2.4 The Availability of Pure Methamphetamine in the United States (2001–2006)

Table 4.9 presents the estimates of the total available methamphetamine from STLs, DSLs, and imported methamphetamine from Mexico from 2001 through 2006. The last two rows are estimates of the total available methamphetamine by year using the two methods described above.

Table 4.9. Availability Trend of Methamphetamine over Time (Metric Tons)

	2001	2002	2003	2004	2005	2006
Availability from STLs [a]	16.2	18.2	20.0	19.9	11.9*	7.9
Available from DSLs[b]	73.3*	42.9	38.7	16.1	10.1	5.4
Available from Mexico						
Method 1[c]	6.6	41.0	60.5	99.1*	122.3	130.8
Method 2[d]	21.3	24.2	36.3	99.1*	122.1	133.2
Total Availability						
Method 1	96.1	102.0	119.2	135.1	144.3	144.1
Method 2	110.8	85.2	95.0	135.1	144.3	144.1

* These values are based on key known figures and the below-referenced trends used to estimate values for other years.

[a] Estimated using trends in clandestine laboratory seizures for STLs, using 2005 as a starting point. The 2005 estimate was calculated from the 2005 precursor methodology. Calculations are presented in the table.

[b] Estimated using trends in clandestine laboratory seizures for DSLs, using 2001 as a starting point.

[c] Calculated using consumption trend path (from Quest data) as upper limit of production, with total production in 2004 as a starting point.

[d] Calculated from total methamphetamine produced in Mexico for 2001 (see Table 4.4) through 2004 and consumption trends for 2005 and 2006.

As these estimates indicate, changes to or restrictions on both precursor imports and law enforcement focus on laboratory seizures in the presence of increasing consumption demands may have altered the configuration of the methamphetamine market; that is, the quantity of methamphetamine produced by STLs and DSLs declined while foreign imports of finished product increased.

4.3 Comparison of Methamphetamine Availability Estimates to Other Sources

The following section compares the estimates of methamphetamine availability (presented above in Table 4.9) with other indicators of illicit drug availability. *Section 4.3.1* compares the supply-based estimates with demand-based estimates; *Section 4.3.2* examines treatment admissions data; and Section *4.3.3* examines trends in methamphetamine prices.

4.3.1 Demand-based Estimates

A companion report, *What America's Users Spend on Illegal Drugs,* provides estimates of the number of methamphetamine users, the amount that they spend on methamphetamines, and the tonnage of use (ONDCP, 2011). According to that report, the number of chronic methamphetamine users (defined as weekly or more frequent use) increased from 823,000 in 2000 to 1.3 million in 2006. Total expenditures on methamphetamine grew from $11.7 billion to $17.9 billion for that same period. Tonnage of use increased from 65.6 metric tons in 2000 to 167.4 metric tons in 2005 before falling to 157.3 metric tons in 2006.

These demand-based estimates are estimated with considerable uncertainty. Nevertheless, the scale is consistent with that observed for the supply-based estimates. Moreover, the trends are estimated with greater precision, and the supply-based and demand-based trends are broadly consistent.

4.3.2 Treatment Admissions

The companion report also provides estimates of trends in treatment admissions for methamphetamine as the primary or secondary drug of admission. Outpatient treatment admissions grew from 55,000 in

2000 to 127,000 in 2006. Inpatient treatment admissions increased from 37,000 to 62,000 over that same period. These trends in treatment admissions are parallel to trends in tonnage of use.

4.3.3 Price Trends

It is difficult to anticipate how prices should behave when demand is expanding. Fries et al. (2008, P. 11) report:

> STRIDE d-methamphetamine data are volatile, and may be sparse depending on the time period and location. The time series for the annual predicted price of one expected pure gram of d-methamphetamine behaved similarly at the national and major southwest city levels. There were peaks in 1995–1996, 1998, and 2006–2007 coincident with the introductions of methamphetamine precursor chemical regulations. In between peaks, estimated price per pure gram declined steadily, e.g., falling more than 50 percent between 1998 and 2005.

While their observations seem sensible, they do not cover the period of interest here. Figure V-1 on page V-4 of the report provides strong evidence that methamphetamine prices have declined between 2000 and 2005, inclusive, and may have increased in 2006. If increasing availability of methamphetamine has driven increasing use of methamphetamine, one might expect prices to fall over this period. Thus trends in price estimates are consistent with trends in use.

Chapter 5:
Availability of Marijuana

5.1 Summary

When estimating the availability of marijuana to the United States, the Working Group's methodology (hereafter the *extant methodology*) used a simple logic employing three assumptions (Drug Availability Steering Committee, 2002). The first assumption is that all marijuana comes from Mexico or is produced in the United States.[85] This assumption understates marijuana availability because some marijuana produced in other countries is destined for the United States, but the understatement is arguably small. The second assumption is that Mexican marijuana is mostly destined for cash markets in the United States, so what does not get eradicated, seized or consumed in Mexico is available for sale in the United States. The third assumption is that marijuana eradicated in the United States is a fixed proportion of marijuana produced in the United States. Arguably, the proportionality assumption holds over time because the technology for detecting marijuana production has not much changed during the last decade. Of course the proportionality is unknown, but given an assumption about eradication rates, the potential amount of marijuana available for sale equals (1) the amount eradicated divided by the eradication rate plus (2) the net Mexican potential production. Subtracting domestic seizures from the potential amount available for sales gives the availability of marijuana to the United States according to the extant methodology.

This logic is simple and seemingly compelling yet problematic. Researchers have provided consumption-based estimates of amounts and trends in marijuana use in the United States. These estimates come from highly regarded surveys: the National Survey on Drug Use and Health (NSDUH), the Monitoring the Future (MTF) survey, the Youth Risk Behavior Surveillance System (YBRS), and the Arrestee Drug Abuse Monitoring (ADAM) survey. Although these surveys show changes over time in the use of marijuana, the changes are small: marijuana consumption appears to have been relatively constant during the last decade. This constancy contrasts with marijuana availability estimates from the extant methodology, which show marked increases (see Table 5.1 below). Furthermore, researchers have provided price estimates for marijuana purchased in the United States. These estimates come from credible sources including the System to Retrieve Information from Drug Evidence (STRIDE), the NSDUH and ADAM. While price series show fluctuations, there is no large downward trend in marijuana prices as one might expect if marijuana production were increasing while demand remained constant.

Table 5.1. Total Marijuana Available in the United States based on the Extant Methodology (Metric Tons)

	2001	2002	2003	2004	2005	2006
Marijuana	11,003	15,245	21,306	18,130	22,102	26,659

85 According to the extant methodology, marijuana also comes from Canada, but relative to Mexico and the U.S., the Canadian supply is small. For simplicity, the argument presented in this paper ignores marijuana from Canada, although the argument would not much change if Canadian production were included.

The discrepancy between supply-based and demand-based estimates is difficult to resolve with the available data. One might find fault with the consumption data, and it is plausible that consumption data understate the amount of marijuana use because survey respondents deny or understate their use (Harrison et al., 2007). It is less plausible that consumption data radically distort trends. One might find fault with the STRIDE data (Horowitz, 2001), but it is more difficult to fault price trends from the NSDUH and ADAM, and those sources are consistent with STRIDE that there are no downward trends in prices. Something appears to be wrong with the supply-based estimates. Therefore, this chapter poses two questions: Are there reasons to doubt the extant methodology for estimating marijuana availability to the United States? Is there an alternative way to estimate availability to the United States?

Most of the chapter is devoted to answering the first question, and the conclusion is that the extant estimation methodology is not credible.[86] Consequently, except for Table 5.1 above, those estimates are not detailed in this chapter. The answer to the second question is speculative. It would be possible to build supply-based models based on marijuana prices and the responsiveness of demand to prices (demand elasticity), but this would be a very different approach than basing estimates on observations of Mexican production and U.S. eradication. A necessary approach may be to rely on demand-based estimates, which appear credible for reasons explained in this report.

The argument progresses as follows: ***Section 5.2*** uses an economic model of supply and demand to provide a basis for inferences about marijuana markets. Using that supply and demand model, it argues that knowledge of eradication amounts and Mexican potential production estimates are inadequate for drawing inferences about marijuana availability to the United States. The next two sections are empirical. ***Section 5.3*** provides trends in marijuana prices taken from three independent sources of data. All three trends are consistent: marijuana prices have not changed much over the last decade. ***Section 5.4*** provides trends in marijuana use taken from multiple sources. The evidence shows that over the last decade marijuana use has declined for youth and remained fairly constant for everyone else. ***Section 5.5*** summarizes and suggests an alternative approach to the extant methodology.

5.2 Supply and Demand: Background for Considering the Problem

Economics students quickly learn the simple logic of supply and demand. Notable economists have argued persuasively that the logic of supply and demand extends to illegal drug markets including marijuana markets (Becker et al., 2006; Manski, et al., 2001) and have applied economic modeling to better understand the effectiveness of anti-drug programs (Mejia, 2010; Chumacero, 2010). This section posits a simple model of supply and demand and uses it to argue that the extant methodology is not credible. The model is purposefully simple so that it makes fundamental points without undue complications.

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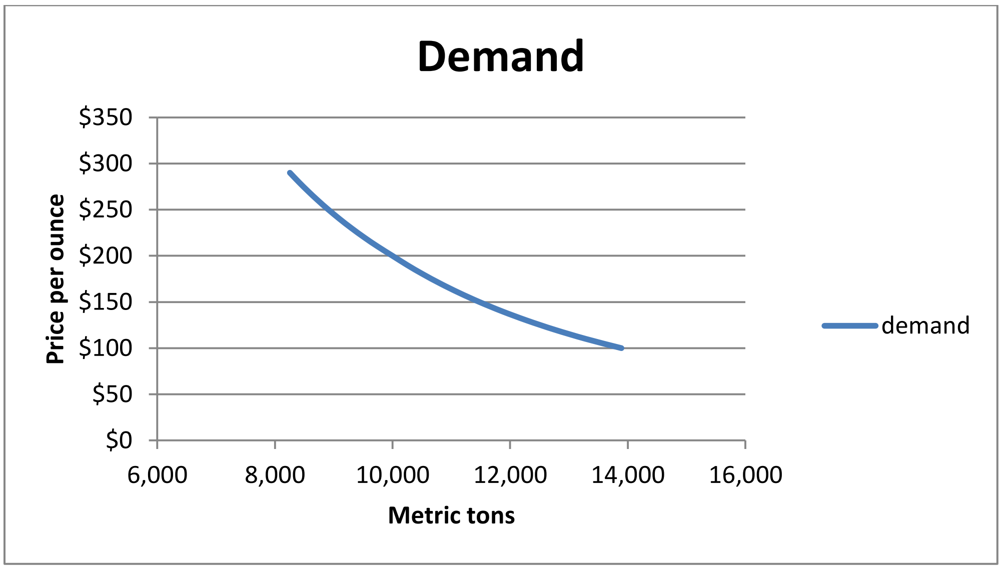
[86] The National Drug Intelligence Center (2010) reached a similar conclusion in the National Drug Threat Assessment 2010 with respect to domestic cultivation. From note 16 on page 36: "No reliable estimates are available regarding the amount of domestically cultivated or processed marijuana. The amount of marijuana available in the United States—including marijuana produced both domestically and internationally—is unknown. Moreover estimates as to the extent of domestic cannabis cultivation are not feasible because of significant variability in or nonexistence of data regarding the number of cannabis plants not eradicated during eradication seasons, cannabis eradication effectiveness, and plant yield estimates."

5.2.1 The Demand for Marijuana

Economists recognize that the demand for any consumption good is a function of the unit price and other factors. The other factors include the perceived benefit from the good, the perceived harm, social acceptability, and so on. For this discussion, assume that these other factors do not change, so that unit price is a buyer's only consideration when purchasing marijuana.[87]

Figure 5.1 is a hypothetical illustration of the demand curve for marijuana. It represents the combined demand by all marijuana buyers. The curve assumes an elasticity of -0.5. This means that if price increases by X percent that demand will fall by about 0.5X percent. This seems like a reasonable price elasticity of demand for marijuana,[88] and adopting alternative yet reasonable assumptions would not change the important argument.

Figure 5.1. The Demand for Marijuana (Hypothetical)



[87] Economists distinguish between shifts of the demand curve and movement along the demand curve. For present purposes, a change in price causes a movement along the demand curve. A change in perceptions of risk and benefits would cause a shift of the demand curve. In this regard, the argument holds the demand curve constant.

[88] Citing work by Pacula and others at Rand, Grossman, Chaloupka & Shim (2001) conclude that a conservative lower bound for marijuana price elasticity is about -0.30 and an upper bound is likely larger than -0.69. A later Rand study uses -0.54 as a best estimate but notes that estimates are imprecise (Kilmer, Caulkins, Pacula, MacCoun, & Reuter, 2010, p. 23). Becker et al. (2006) note that "There are no reliable estimates of the price elasticity of demand for illegal drugs.… However, estimates for different drugs generally indicate an elasticity of less than one in absolute value, with a central tendency of about one-half … although one or two studies estimate a larger elasticity.…" Using economic reasoning and a review of elasticity studies for various goods, Clement (2005) argues that without better information, a researcher should assume that the elasticity is about –0.5. This advice is consistent with elasticity estimates for alcohol and tobacco (Fogarty, 2004; Gallet, 2007; Wagenaar et al., 2009; Gallet & List, 2003).

The demand curve is conventional. To sell 10,000 metric tons of marijuana, dealers would have to charge about $200 per ounce. They would have to set a lower price to sell more and they could set a higher price if they were willing to sell less.

The demand curve is hypothetical but not unreasonable. As noted earlier, an elasticity of demand equal to -0.5 is not inconsistent with the literature. That markets clear at 10,000 metric tons assumes that more marijuana is used than is shown by demand-based studies but less than is shown by supply-based studies. An average price of $200 per ounce is in the range of available estimates. Moreover, accuracy of these numbers is not essential for the argument.

5.2.2 The Supply of Marijuana

Dealers have a supply curve. There are many producers and sellers, so it seems reasonable and conventional (Becker et al., 2006) to discount monopoly power and assume that dealers sell at a price that covers production and distribution costs, and that provides an acceptable return on producer/distributor time and investments. Some readers might like to think of the latter as profit, although economists reserve that term for other purposes. If there were monopoly power, the main conclusions would not change, but the argument would be more complicated.

A simple cost equation will suit present needs. In this simple cost equation, there are three cost components. An illustration might help. In the California national forests, Mexican entreneurs sell the equivalent of franchises to plant, cultivate and harvest marijuana. The entrepreneurs identify the plots and provide the materials and labor. The franchisee bears the risks that enforcement agents will discover the illegal use of national forest land and destroy the crop. The franchisee brings the marijuana to market.[89]

Using this illustration, the first of three cost components is the cost of clearing, planting and cultivating the growing area—typically about eight hectares per plot in the national forests. Call the cost per unit produced CA.[90] The second cost component is the expense of harvesting and moving the marijuana from the forest to a collection point. Call this cost CB. The third cost component is the expense of moving the marijuana to market and eventually selling it on the street. Call this cost CC. This third component has many subcomponents, but recognizing those subcomponents will be unnecessary for this argument.

Dealers will provide marijuana at retail for a price of $C_A + C_B + C_C$. The production and distribution costs increase more than proportionally with the amount supplied, so the supply curve is upward sloping, presumably because additional producers demand higher prices to overcome risk (Pacula, Kilmer, Grossman, & Chaloupka, 2010). Figure 5.2 shows an illustrative supply curve divided into its component parts.

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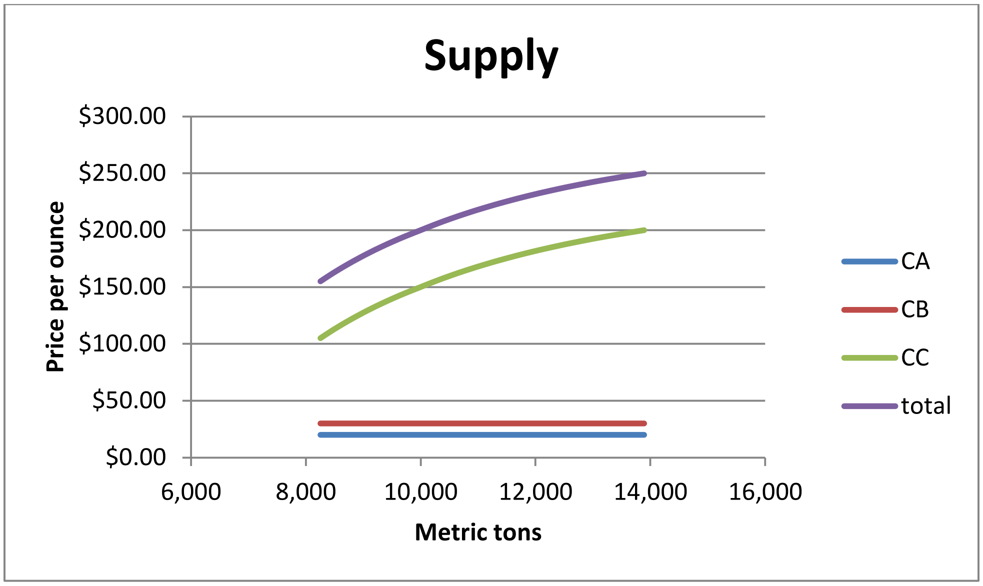
89 The illustration comes from a visit to Yosemite National Park in the fall of 2009. Rangers showed our team growing areas and discussed the process of planting, cultivating and harvesting marijuana in the park. Undoubtedly there are other business models even within Yosemite and certainly in other state and Federal forests and across California and the nation.

90 The unit produced is the equivalent of one ounce of commercial marijuana. Alternatively one might think of the unit produced as a marijuana plant, but this would simply complicate the algebra.

Figure 5.2. The Supply of Marijuana (Hypothetical)



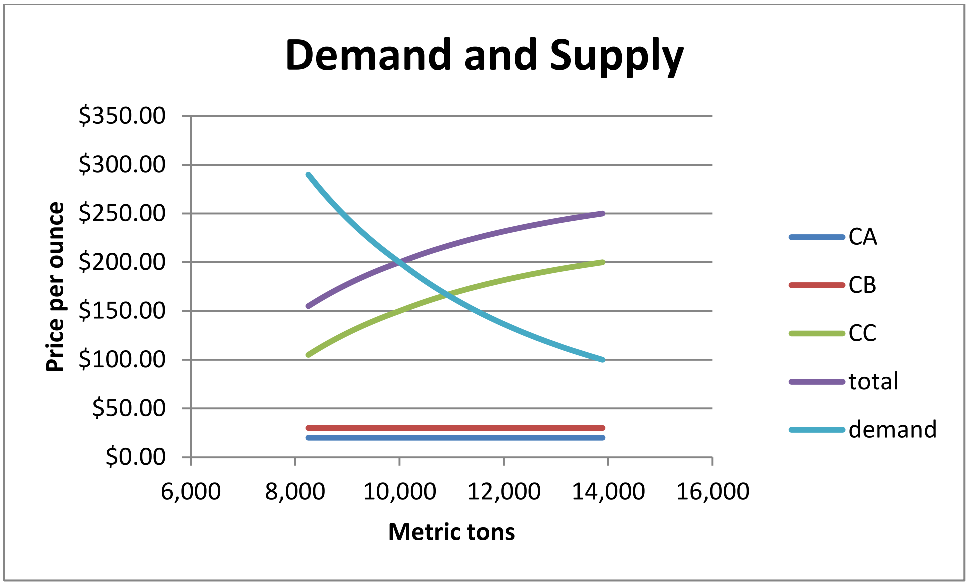
This illustration assumes that the cost of clearing and cultivating a field (CA) is $20 per ounce of marijuana produced regardless of the total quantity produced. It assumes that the cost of harvesting and moving the crop to a collection point is $30 per ounce of marijuna regardless of the total quantity produced. The cost of distributing the marijuana beyond the collection point increases with the total amount of marijuana that enters the market. These assumptions allow CA and CB to represent 29 to 44 percent of the retail price, which almost certainly is too high.[91] Using more realistic ratios of CA and CB to CC would reinforce the points made below.

5.2.3 Demand and Supply

The next step is to superimpose Figure 5.1 (the demand curve) onto Figure 5.2 (the supply curve), as shown in Figure 5.3.

[91] This report will present estimates of marijuana prices from the Institute for Defense Analysis. IDA reports price estimates for purchases of 10 grams or less, between 10 and 100 grams, and more than 100 grams. Prices for more than 100 grams are surely higher than farm gate prices, but if we nevertheless use them as farm gate prices, the price for purchases of less than 10 grams is about 20 percent of the farm gate price and the price for purchases between 10 and 100 grams is about 34 percent of farm gate price. An older report (ONDCP, 2001) provides price estimates for purchases of less than 10 grams, for purchases of 10 to 100 grams, and for purchases in excess of 1 kilogram. The 1 kilogram purchase price likely come closer to farm gate costs, but certainly it exceeds farm gate costs. If we accepted it nevertheless as farm gate costs, then CA + CB is 13 percent of the price for purchase of 10 grams or less and 17 percent of the price for purchases between 10 and 100 grams. It is unlikely, then, that CA + CB accounts for near 29 to 44 percent of the price of marijuana. Also see a recent report from Rand (Kilmer et al., 2010). Gettman (2006) disagrees: "…a farm price would be 50 percent of retail.… These are simplifying assumptions that are generally consistent with market conditions as reported in the press and government reports." The reports are not cited.

Figure 5.3. The Supply and Demand for Marijuana (Hypothetical)



In this figure, the market clears at a price of $200 per ounce of marijuana, which results in 10,000 MT of marijuana sold at retail. If buyers tried to pay less, as a collective they would be unable to purchase more than 10,000 metric tons, because sellers would demand too high a price. If sellers tried to charge more, as a collective they would be unable to sell more than 10,000 metric tons, because buyers would refuse to buy that much. The market clears at $200 and 10,000 metric tons.

The figure simplifies a more complicated process of market transactions. Transactions do not take place in a single market, and in fact there are various forms of marijuana, so prices vary over diverse markets and over grades of marijuana. Nevertheless, the simplification is useful because it provides a way to discuss the role of enforcement.

5.2.4 Market Dynamics

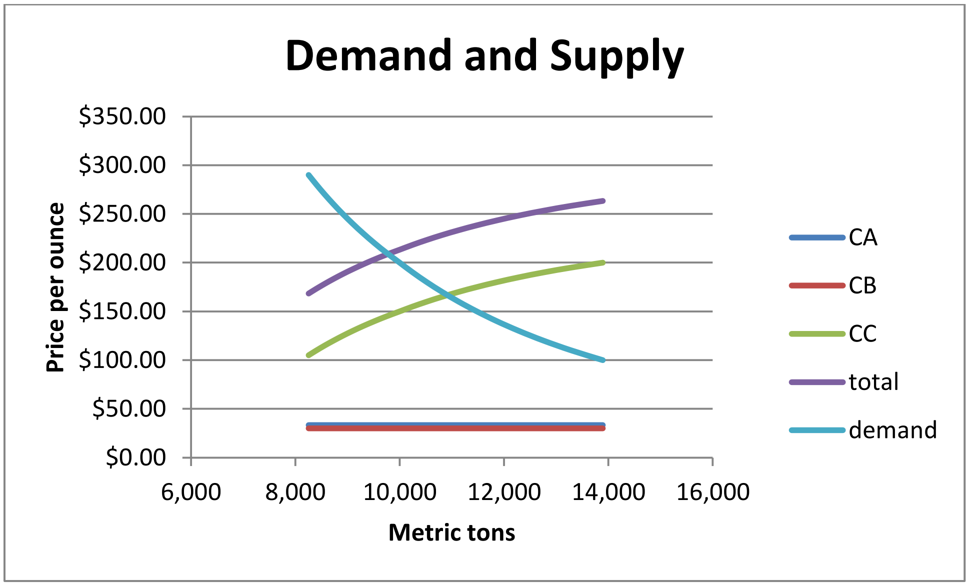
So far the model has ignored eradication, but it is unreasonable to assume that producers fail to take the threat of eradication into account. This subsection assumes that producers anticipate eradication and that they treat it as a cost of doing business. This realistic assumption has profound effects on the way that marijuana markets operate.

For example, what if the government were able to eradicate 4,000 metric tons of marijuana, or 40 percent of the amount that would clear the market in the absence of enforcement? A view that ignores market dynamics would imply that only 6,000 metric tons would move to market, and prices would increase from $200 per ounce to above $350 per ounce to allow the market to clear. (The solution is not shown on the figure.) The problem with this solution is that it is naïve about market behavior. Assume that as a collective, producers know that about 40 percent of their crops will be eradicated.[92] What is a rational response from a business perspective? To answer this question, suppose at first that

[92] Economists often make assumptions that may be jarring to the sensitivities of non-economists. How could a producer *know* that 40 percent of his crops would be eradicated? In fact, it seems more likely that a producer will estimate a 0.40 chance that all his crops will be eradicated and a 0.60 change that none will be eradicated,

eradication occurs after fields are cleared, planted and cultivated but before they are harvested and the marijuana is collected for distribution to the market. Without government intervention, the cost of clearing, planting and cultivating is CA. Because 40 percent of the cultivation will be eradicated, the cost of marijuana that escapes enforcement is increased to CA/0.6. In the illustration above, the cost CA was $20 per ounce of marijuana equivalent. Now the cost is $33.33 because the producer must plant 10 hectares for every 6 hectares that avoid eradication. Otherwise the dynamics of market behavior remains the same. Figure 5.4 shows the results of increasing CA from $20 to $33.33.

Figure 5.4. Market Adjustments to Increasing CA



The upward shift in the supply curve is almost imperceptible because these changing costs account for very little of the total supplier cost, which is largely unaffected by eradication. It suggests that the market clearing prices will be slightly higher and that the market clearing amount will be slightly lower—somewhere near 9,700 metric tons. This 300 metric tons reduction is far less than the 4,000 metric tons suggested by the logic of the extant methodology.

Alternatively, eradication might occur as fields are being harvested. Continuing the above illustration, CA would increase to $33.33 as before, and CB would increase from $30 to $50. Figure 5.5 shows the market dynamics.

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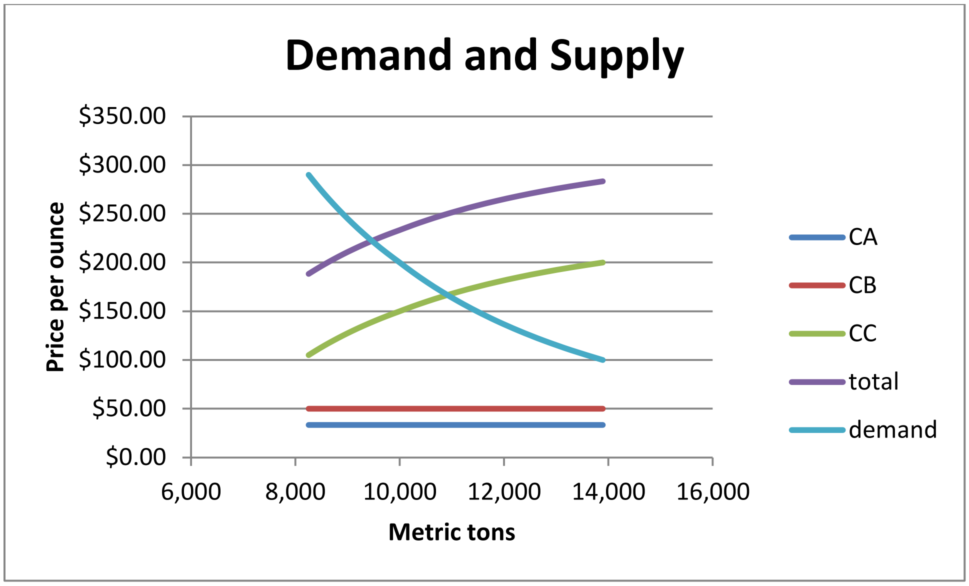
and the producer may not even estimate those probabilities accurately. Assuming that producers have this information is useful for modeling supply, but all that is essential for telling the story is that (1) producers observe that if they produce too much they will have trouble finding buyers who will pay a price acceptable to the producer, and (2) producers will observe that if they produce too little they will forego earnings, and (3) producers make allowances for the costs imposed by enforcement. Producers need not have perfect information about enforcement and markets.

Figure 5.5. Market Adjustments to Increasing CB



The shift in the supply curve is greater than before, and consequently there are greater repercussions for the market. The market clearing price is close to $220 per ounce and the market clearing amount is about 9,500 metric tons.

Neither answer—9,700 metric tons or 9,500 metric tons—is near the estimate of 6,000 metric tons based on the logic of the availability model. Furthermore, the adjustment would be smaller if the argument had used more realistic estimates for CA and CB. However, this criticism is a bit contrived. To explain, assume that eradication happens before plants are harvested, and assume that the market adjustments have occurred, meaning that producers anticipated a 40 percent eradication rates before they plant. Then 9,600 metric tons are sold at market. Because the eradication rate is 40 percent, 16,000 metric tons must have been planted, and 6,400 metric tons must have been eradicated.

The only way that eradication could have a large effect on the market is if producers underestimated the eradication rate and produced too little marijuana. But even underestimating the eradication rate is likely to have a small effect. Given that marijuana is cheap to produce, a prudent step would be to produce more than could be sold as an insurance policy against underestimating the effectiveness of law enforcement practices.

As a barometer on enforcement effectiveness, the extant methodology is defective: Specifically, eradication does not reduce the amount of marijuana that moves to market by an amount equal to the amount eradicated. As a means to produce estimates of availability, it appears acceptable because it involves an accounting tautology: What is not eradicated is available for market. However, even this appearance is deceptive for reasons explained next.

5.2.5 Trends in Eradication

To continue the above observation, the extant methodology is an accounting model. If A metric tons are eradicated, and if B is the proportion of marijuana that is eradicated, then A/B is the amount of marijuana available to market. That tautology is undeniable, and this is why the extant methodology seems appealing.

The problem with an accounting model is that **it requires that the eradication rate remain the same over time** because there is no way to know how the seizure rate (B above) changes over time. One assertion in favor of assuming that the seizure rate is constant is that detection methodology has not changed much over time. That is, enforcement relies on informants and intelligence, because marijuana plots are difficult to detect from the air or ground without knowing where to look. Another assertion is that while additional resources could lead to higher detection rates, investments in enforcement have not grown markedly over time.

The truth of these assertions is difficult to judge. First, we could find no breakdown of enforcement budgets for eradication. If those budgets have increased (for example, DEA's overall budget has increased, so expenditures on its cannabis eradication program have likely increased), this would suggest that eradication rates have increased. Moreover, contrary to the assertion that technology has been static, both NDIC and DEA claim that outdoor detection has improved (NDIC, 2010, p. 39; Drug Enforcement Administration, 2010). Therefore, it seems likely that eradication rates have increased, contrary to assumptions made by the extant methodology. Both assertions necessary for justifying the extant methodology seem wrong.

Even if enforcement technology has not have changed much over time, production processes may have changed, causing eradication rates to increase.[93] Most of the data in Table 5.2 comes from the Criminal Justice Sourcebook using data provided by the DEA; the first data point comes from NDIC. Plots and plants are those eradicated through DEA's Domestic Cannabis Eradication/Suppression Program. The table also reports the number of plants per plot. Statistics are given by year; a source for 2002 was lacking. The table is divided into outdoor growing areas and indoor cultivation. For present purposes, the table is further divided into the entire U.S., California only, and the rest of the United States exclusive of California.

Some observations are worthwhile. Examining outdoor cultivation, eradication has increased from about 3.3 million plants in 2001 to about 4.8 million plants in 2006. If the eradication rate had remained the same, this trend suggests that the domestic production of marijuana has increased by 45 percent. However, something has changed in these data. Over this same period the number of plots eradicated

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93 Producers might take steps to reduce eradication, but this may not be the optimal strategy. The producer's incentive should be to reduce costs not reduce eradication per se. Surely the largest cost comes from having assets (especially land) seized and from being arrested, convicted and incarcerated. This cost can be reduced by moving production from private landholdings to public land and hiring seasonable labor to tend to the crop. Fields on public land may be easier to detect. Hence eradication would increase while costs would decrease relative to what costs would be if the marijuana were grown on private landholdings. Researchers at NDIC (2010, p. 37) agree: "Public lands are often used for cannabis cultivation because DTOs benefit from the remote locations that seemingly limit the chance of detection and allow them to maintain such activities without ownership of any land that can be seized by law enforcement or tracked back to the participating member." The Drug Enforcement Administration appears to disagree (2010): "In many areas of the U.S., cultivators have been forced to abandon large outdoor cannabis plots in favor of smaller, better concealed illicit gardens."

has fallen from near 38,000 plots to near 26,000 plots per year. According to a simple calculation, the number of plants per plot has increased correspondingly. The pattern is especially pronounced in California where the number of plants per plot has increased from about 631 plants to about 1,840 plants per plot.

It is difficult to know what to make of these patterns. A plot is not a standard unit. There is little reason to suppose that marijuana growers would pack more plants into the same acreage, so the assumption is that plots represent increasingly larger cultivation areas.[94] It also seems reasonable that larger plots are easier to detect, and if that is the case, then the eradication rate would have increased without improvements in technology for detecting growing areas.

Table 5.2. Marijuana Plant Eradication DEA Domestic Cannabis Program

		National			*California*			*Rest of Country*		
	Year	***Plots***	***Plants***	***Plants/ Plot***	***Plots***	***Plants***	***Plants/ Plot***	***Plots***	***Plants***	***Plants/ Plot***
Outdoor	2001	37,926	3,304,760	87	1,900	1,199,818	631	36,026	2,104,942	58
	2003	34,362	3,427,923	100	1,880	1,109,066	590	32,482	2,318,857	71
	2004	29,600	2,996,225	101	1,502	1,152,539	767	28,098	1,843,686	66
	2005	29,950	2,938,151	98	1,624	1,904,230	1,173	28,326	1,033,921	37
	2006	26,094	4,830,766	185	1,517	2,791,726	1,840	24,577	2,039,040	83
Indoor	2001	2,379	236,128	99	372	113,009	304	2,007	123,119	61
	2003	2,678	223,183	83	451	72,891	162	2,227	150,292	67
	2004	2,987	203,896	68	428	61,881	145	2,559	142,015	55
	2005	2,959	270,935	92	572	107,047	187	2,387	163,888	69
	2006	3,274	400,892	122	575	203,559	354	2,699	197,333	73

The number of indoor growing areas that are detected and eradicated has grown steadily over time. Although numbers from California are perplexing for 2006, the size of indoor growing areas has not changed much over the decade. Indoor growing areas are detectable by monitoring electricity consumption and by remote sensing devices because of the energy they consume and the heat that they emit. Possibly the eradication rates have increased for indoor growing areas because of technological improvements in remote sensing, but that is speculation.

Although Table 5.2 makes the point that eradication rates appear to be increasing, Table 5.3 completes the eradication picture by reporting eradication by the Forest Service and the U.S. Department of the Interior. Numbers for 2001–2003 are transcribed from DAEUS. For 2004 through 2006 they come from the NDIC (2010). We note that the two sources differ for overlapping years 2004 and 2005 (1,212 and 1,608, respectively, from DAEUS).

[94] This evidence contradicts DEA's observation in the previous note that "In many areas of the U.S., cultivators have been forced to abandon large outdoor cannabis plots in favor of smaller, better concealed illicit gardens." Some producers may have behaved this way, but the evidence is that most producers moved to larger but more remote locations.

Table 5.3. Eradication Reported by the Forest Service and U.S. Department of the Interior (Thousands of Plants)

Year	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*
Plants	946	726	1,000	1,013	1,255	1,836

The evidence from the Domestic Cannabis Eradication Program and from the Forest Service/DOI is consistent with higher rates of detection and eradication during the last decade. If this is true, it would cause a serious upward bias in the estimates of marijuana availability based on the extant methodology.

5.2.6 Other Questions about Eradication Statistics

So far the argument has not challenged the accuracy of the eradication statistics, but there is cause to question their accuracy. Details about the assembly of those statistics are unavailable, but there are a few known facts.

According to the Criminal Justice Sourcebook, the statistics for plant eradication include an unknown amount of ditch weed, a form of marijuana that has no commercial value. This would overstate the eradication of plants, although we do not know if it would distort trends.

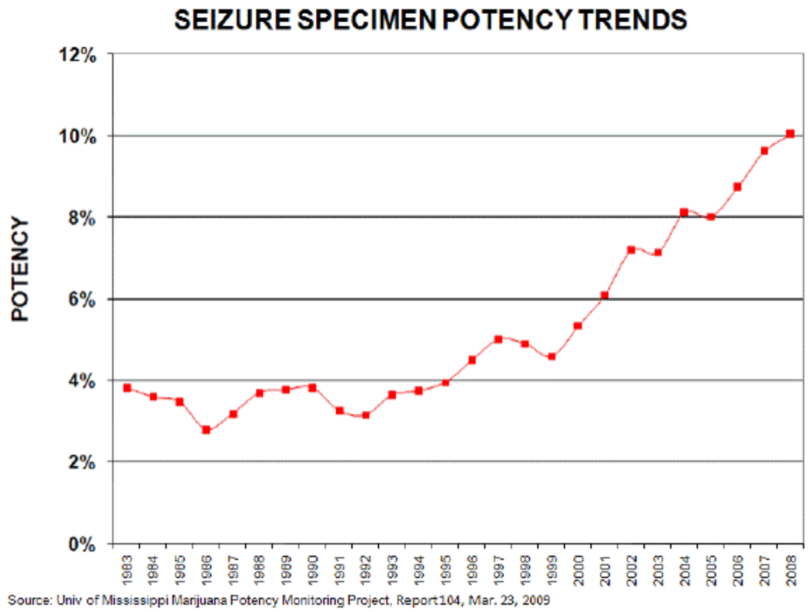
Another problem is that the count of plants is ambiguous and undocumented. If the field is eradicated before it is ready for harvest, then the count includes male plants that would die before harvest, and it would include females that would not reach maturity. Again, we are unsure that this bias would affect trends, but given that much of the trend comes from eradication in public lands, the bias may be substantial.

Although not shown in the table, the extant methodology translates plants into marijuana equivalents using a standard conversion of 448 grams per plant (Drug Enforcement Administration, 1992). Many observers find that this conversion rate is much too high (Bouchard, 2008). The DEA figure is for female outdoor cannabis plants grown under relatively ideal conditions. Marijuana fields are often hidden. In the national forest, they are typically concealed under a canopy of other growth in order to hinder detection. It seems unlikely that these are ideal growing conditions, and it seems plausible that the trends have been toward: (1) lower yields and hence (2) more cultivation and (3) higher levels of eradication.

Related to the above point, the University of Mississippi's Potency Monitoring Project analyzes marijuana seizure including cannabis, hashish, and hash oil samples confiscated by law enforcement agencies. Figure 5.6 was taken from an ONDCP press release of findings so it shows years that are otherwise outside the timeframe of this report.[95]

[95] http://www.whitehousedrugpolicy.gov/pda/051409.html. Downloaded on June 25, 2010.

Figure 5.6. Average Marijuana Seizure Potency Exceeds 10% in 2008



Recent increases in potency are startling. The University of Mississippi does not receive a random sample of marijuana, so some of the trend could be attributed to sampling procedures. But likely sampling procedures cannot challenge a conclusion that potency has increased greatly over the last decade. One implication is that growers may be becoming increasingly selective when marketing. Buds have the highest potency, leaves have the next highest potency, and stems have the least potency (ElSohly, n.d.). Possibly producers are increasingly moving buds to market and discarding leaves and stalks.[96] If so, an assumption that yields per plant are constant would overstate trends in marijuana availability.

5.2.7 Mexican Potential Production

Mexico provides large amounts of marijuana to the United States. Table 5.4 provides some estimates to serve as talking points. The first row identifies the year and the second row identifies production estimates in metric tons. The first two years are from the original DAEUS; the rest are from the NDIC threat assessment (NDIC, 2010). The third line represents seizures on the Southwest Border, also taken from the NDIC report. The final row is the ratio of Southwest Border seizures to Mexican potential production potential after subtracting 2 metric tons from potential production to account for seizures internal to Mexico and Mexican consumption.

96 Table 7 (ElSohly, n.d.) is suggestive. It provides the number of domestic seizures by DEA divided into bud, loose leaf, and other categories. A linear trend shows that bud grew from 40 to 70 percent of seizures between 2000 and 2008. Most of the increase occurred in the first few years. Domestic seizures can also be divided into marijuana and sinsemilla (ignoring ditch weed). The growth in the proportion of domestic seizures that are sinsemilla increased linearly from 10 percent to 60 percent over that same period.

Table 5.4. Mexican Potential Production and Southwest Boarder Seizures (Metric Tons)

Year	2001	2002	2003	2004	2005	2006
Production	7,400	7,900	13,500	10,400	10,100	15,500
Seizures					1,034	1,147
Implied Rate					17%	10%

Two observations are obvious. The first is that reports of Mexican potential production have increased greatly over the decade; the estimate for 2006 is more than double the estimate for 2001. The second observation is that the seizure amount has remained fairly constant so the apparent seizure rates have fallen over the observable period. A falling seizure rate seems implausible because no authority has argued that the ability of border agents to detect marijuana has deteriorated. The implication is that trends in production are overstated or that much of the Mexican marijuana is not moving to market. This point is returned to later in this report.

The third observation is not so obvious because this report has not yet discussed consumption estimates. To foreshadow, consumption-based estimates are well under 10,000 metric tons, and there is no evidence of trends toward more marijuana use. After adjusting Mexican potential production for seizures and Mexican-based consumption, and after accounting for U.S. domestic production and a small amount of Canadian production, the extant estimation methodology produces results that are grossly discrepant with drug use indicators.

Explanations are elusive. Part of the explanation may be that production estimates are inaccurate. To explain, production is the product of hectares under cultivation and yield per hectare. The former is provided by CNC, and the latter is provided by the Mexican Government. Possibly the yield estimates (from 1997) should be declining over time, but this is speculative.[97]

5.2.8 Overview of Availability

If domestic eradication rates are proportional to domestic production, and if Mexican marijuana mostly moves to U.S. markets, two conclusions are inescapable: Much more than 10,000 metric tons of marijuana are available to U.S. markets, and there is a trend toward increasing amounts of marijuana per year. So far this discussion has advanced two counterarguments. First, from the perspective of a supply-and-demand model, there is no reason to feel confident that increasing seizures reflect more

97 Potential production is estimated from two factors. The first factor is the number of hectares of marijuana under cultivation in Mexico—a figure provided by CNC. A description of crop production methodology comes from multiple sources. Abt Associates benefited from previous exchanges with CNC, including a presentation at CNC on October 21, 2003, and a day-long discussion with CNC staff on December 3, 2003. Additional information came from reviewing documentation (slideshow presentations) and Fossum et al. (2002). "The second factor is the average yield per hectare of cultivation: 1.8 metric tons per hectare per year, based on a 1997 figure provided by the Mexican government. The source of these estimates and their derivation is unknown, and CNC reports that "marijuana yields are under review." Yields likely vary from one growing region to another, but there is currently no growing region-specific information to support different yield estimates. CNC's observation raises a concern that trends confound an increase in hectares devoted to cultivation with changes in productivity of those fields.

production, and even if there is more production, this does not mean that the additional production moves to market. Second, given that Mexican potential production estimates depend on dated and undocumented yield estimates, and given that seizures on the Southwest Border are fairly constant, there is no strong reason to believe that Mexico is shipping increasing amounts of marijuana to the United States.

Estimates from the extant methodology are suspicious. Next we ask the question: Are estimates from the extant methodology consistent with other indicators of drug use? We begin with estimates of marijuana prices.

5.3 Price Changes

Three sources provide information about marijuana prices. The first is the System to Retrieve Information from Drug Evidence (STRIDE), the second is the National Survey on Drug Use and Health (NSDUH), and the third is the Arrestee Drug Abuse Monitoring (ADAM) survey.

Returning to the economic model of marijuana markets, how should prices behave if increasing amounts of marijuana were entering the market? If demand were constant as assumed for convenience in the model, then we should observe (1) a fall in prices and (2) an increase in the amount used. If demand were actually increasing—contrary to the maintained assumptions—prices changes are uncertain but we would certainly observe more marijuana use. Section 5.3 presents an argument that marijuana use has not increased during the last decade. This current section shows that prices have not changed.

5.3.1 Estimates from STRIDE

The Institute for Defense Analysis (Fries et al., 2008) produces STRIDE-based drug price series for the Office of National Drug Control Policy. The latest report provides estimates through 2007, reproduced below in two figures. (The source is Table B6 in the IDA report.) The first of the two figures (Figure 5.7) is based on median prices. The second (Figure 5.8) uses an estimation procedure based on the *expected purity hypothesis*. Readers should consult the IDA report for details.

STRIDE-based estimates are problematic for all drugs (Manski et al., 2001; Horowitz, 2001), but the problem is especially serious for marijuana: there are seldom reasons for DEA to make street-level purchases of marijuana, so data are sparse, estimates are consequently imprecise, and they may be biased.

Figure 5.7. Marijuana Prices Based on Medians

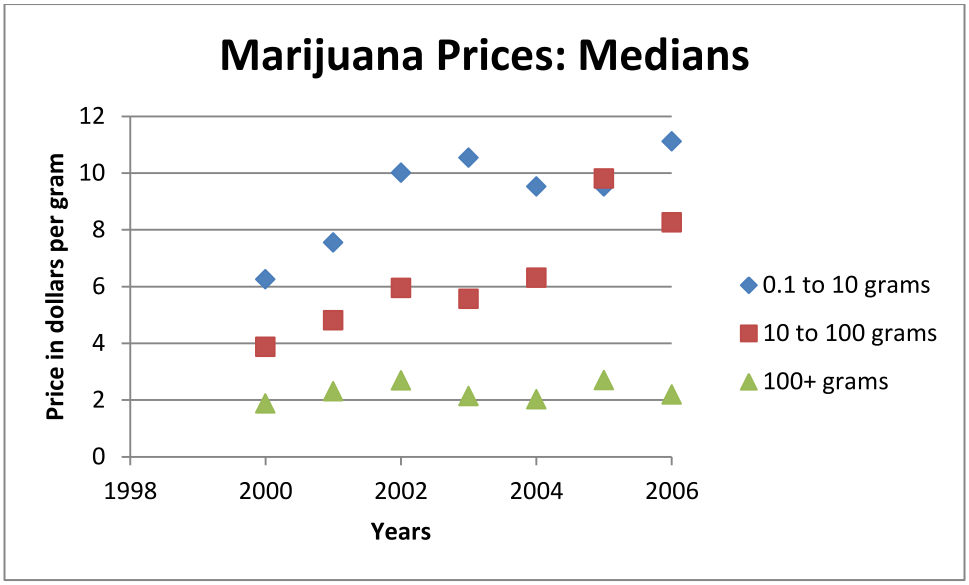
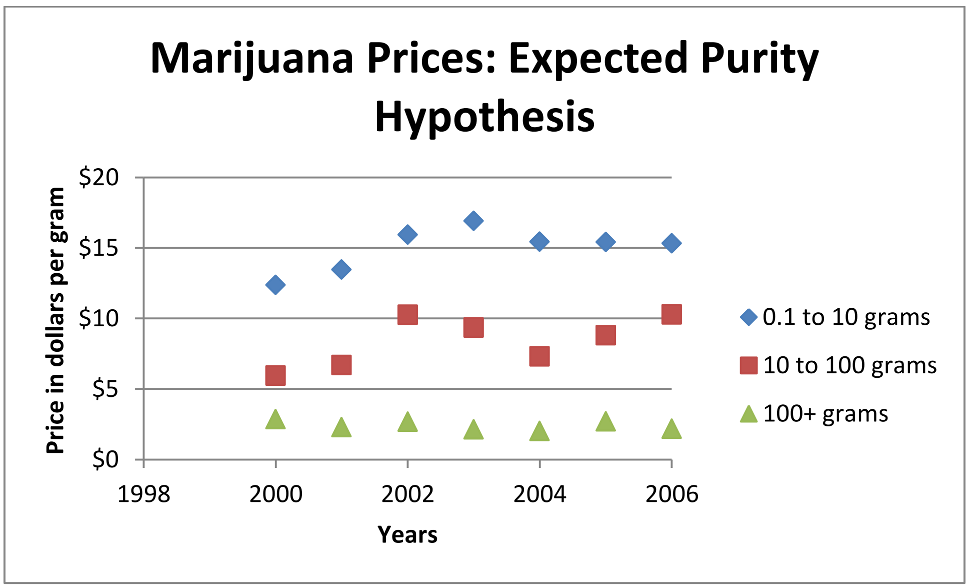


Figure 5.8. Marijuana Prices Based on the Expected Purity Hypothesis



The figures report estimated prices for three categories of purchases. Ranges are exclusive of their upper limits.

For purchases of 100 grams and more, both estimation approaches leave the impression that prices have been fairly constant. For smaller purchases, estimation suggests that prices have increases, and the trend based on medians seems to be larger than the trend based on the expected purity hypothesis. Neither figure suggests that marijuana prices have fallen consistently as might be expected if increasing amounts of marijuana were entering the market. If anything, the figures suggest that retail-level marijuana prices have been increasing, consistent with the view that increased proportions of domestic marijuana cultivation are being eradicated.

Caution is required. The underlying purchase data were collected for enforcement purposes, and whatever bias this imparts is unknown. Nevertheless, other estimates—presented below—agree that there has been no price decline.

5.3.2 Estimates from the NSDUH

Between 2001 and 2008, the National Survey on Drug Use and Health (NSDUH) asked respondents to report how much they purchased during their last marijuana buy and how much they paid. The analysis uses data from all these years to reduce sampling variance. The NSDUH gives respondents a choice for how they want to report prices: by joints, by grams, by ounces, or by pounds. Few respondents report by joints, so joint purchases are discarded from the analysis reported here. Few respondents purchase more than two pounds, so larger purchases are also discarded from the analysis. With one exception, the NSDUH forces responses into categories. The categories are shown in Table 5.5. The exception is for gram purchases in excess of 10 grams. These are reported as continuous measures, and the gram responses can exceed the ounce responses. There are 28.35 grams in an ounce.

Table 5.5. Purchase Amounts by NSDUH Respondents: 2001–2008

Purchase amount	Number of respondents	Percentage
1–5 grams	5,204	45.7%
5–10 grams	2,456	21.6%
10+ grams	583	5.1%
1/8–1/4 ounce	1,103	9.69%
1/4–1/3 ounce	498	4.37%
1/3–1/2 ounce	177	1.55%
1/2–1 ounce	526	4.62%
1-5 ounces	592	5.20%
5–10 ounces	91	0.80%
10–16 ounces	55	0.48%
1–2 pounds	102	0.90%
All	11,387	100.00%

Notes: Tabulations are exclusive of amounts reported as joints and amounts in excess of two pounds.

Table 5.5 shows that most purchases are in the gram range although purchases of one pound or more are not infrequent. Table 5.6 also shows prices paid for purchases. The NSDUH reports these as ranges.

Table 5.6. Prices Paid Reported by NSDUH Respondents: 2001–2008

Price paid	*Number*	*Percentage*
$0 to $5	510	4.5%
$5 to $11	2,578	22.6%
$11 to $21	2,838	24.9%
$21 to $51	3,795	33.3%
$51 to $101	1,016	8.9%
$101 to $151	244	2.1%
$151 to $201	103	0.9%
$201 to $251	74	0.6%
$251 to $301	64	0.6%
$301 to $501	88	0.8%
$501 to $1001	51	0.4%
$1001+	26	0.2%
Total	**11,387**	**100.0%**

Notes: Dollar categories are exclusive of the upper limit.

The present purpose is to determine if prices have increased over time (with time recorded as years) conditional on the amount purchased. Because prices are reported as categories measured on an ordinal scale, an ordered logistic regression is an appropriate way of determining trends. The regression has price categories as a dependent variable. When quantities are reported as ranges, dummy variables represent the ranges; when quantities are reported as continuous gram amounts, the gram amounts enter the regression. Survey years also enter the regression and are the principal independent variable of interest. The regression uses weights and the standard errors are adjusted for the survey's complex sampling design. Results are reported in Table 5.7.

Table 5.7. Regression Results with Price Paid as the Dependent Variable

Variable	*Parameter*	*Standard Error*	*Z-Score*	*P-Value*
YEAR2002	0.082	0.081	1.020	0.310
YEAR2003	0.048	0.101	0.470	0.637
YEAR2004	-0.051	0.100	-0.510	0.608
YEAR2005	-0.056	0.106	-0.530	0.594
YEAR2006	0.098	0.111	0.880	0.377
YEAR2007	0.173	0.104	1.660	0.097
YEAR2008	0.042	0.098	0.420	0.671
1–5 grams	-4.907	0.386	-12.710	0.000
5–10 grams	-4.049	0.380	-10.640	0.000
1/8–1/4 ounces	-3.556	0.392	-9.080	0.000
1/4–1/3 ounces	-3.461	0.399	-8.670	0.000
1/3–1/2 ounces	-3.207	0.425	-7.550	0.000
1/2–1 ounces	-2.096	0.377	-5.560	0.000
1–5 ounces	-0.775	0.395	-1.960	0.049
5–10 ounces	-1.005	0.609	-1.650	0.099
10–16 ounces	-0.990	0.720	-1.370	0.169
Reported as 10+ grams	-3.497	0.449	-7.790	0.000
Grams	0.022	0.012	1.780	0.076
LARGE_METRO	-0.106	0.072	-1.480	0.140

Variable	Parameter	Standard Error	Z-Score	P-Value
SMALL_METRO	-0.056	0.075	-0.760	0.450
AGE	0.190	0.014	13.290	0.000
AGESQ	-0.002	0.000	-10.560	0.000

Table 5.7 shows parameters, standard errors, Z-scores and probability that the parameter is equal to zero. Most of these parameters are of limited interest for this discussion, because they simply show that buyers pay more for larger purchases. ("Purchases of 1–2 pounds" is the omitted category.)[98] Some of the parameters have technical interpretations: they are of no concern here and do not appear in the table. For present purposes, the most useful parameters are those associated with years. The interpretation is clear. Using standard statistical testing (a Wald test), we would not reject the null hypothesis that prices have not changed over time (P=0.27). Not shown here, regressions that substitute linear and quadratic trends for the year dummy variables do not show trends that are statistically significant.

The parameters are abstract and difficult to interpret. More useful is translating the parameter estimates into dollar prices paid for common purchase amounts. The analysis took two approaches. Method 1 requires three steps. First the probability of paying a price within the identified ranges is estimated. This is done for every observation. That probability is then multiplied by the midpoint of the range ($1001 for the highest category) and summed, thereby providing an estimate of the amount paid for every observation in the survey. Figure 5.9 reports the average over the observations for each year. Method 2 requires three steps. First it sets all the covariates equal to their mean values, estimates the probability of paying the amount in each of the 12 price categories, and computes the weighted average across the categories. Figure 5.9 summarizes the results.

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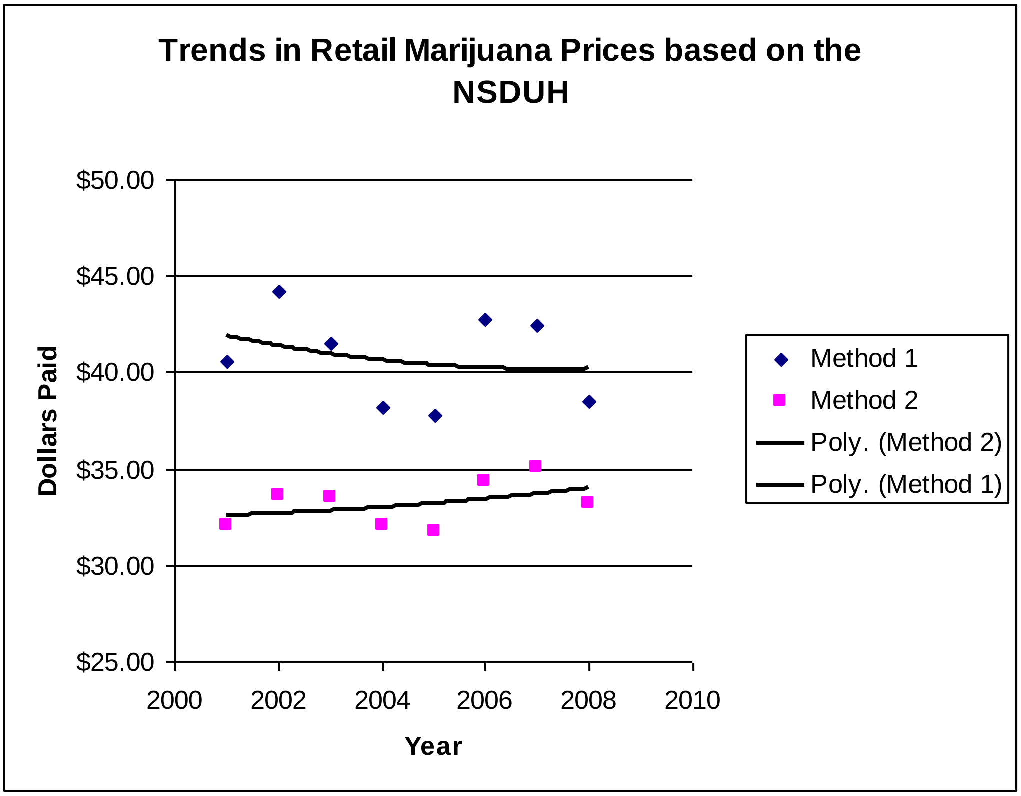
[98] The regression includes the size of the metropolitan area where the interview was conducted and the buyer's age as control variables. The NSDUH did not include the state or region, which would have been useful variables because marijuana prices vary across the U.S. Nevertheless, the regression provides an unbiased estimate of the conditional mean for the price paid by purchase amount.

Figure 5.9. Marijuana Prices According to the NSDUH: 2001–2008



The visual impression from Figure 5.9 is that the two methods provide different answers. According to method 1, prices appear to fall slightly between 2001 and 2008. According to method 2, prices appear to increase slightly between 2001 and 2008. However, the statistical analysis shows that trends are not statistically significant. The most justifiable conclusion is that prices have not much changed over the eight-year period.

5.3.3 Estimates from ADAM

The Arrestee Drug Abuse Monitoring survey provides one more way to monitor marijuana prices. ADAM surveyed a probability sample of arrestee in ten counties from 2000–2003 and from 2007–2010. As before, estimation uses data past 2006 in order to reduce sampling variance. If an arrestee reported purchasing marijuana during the month before his arrest (all respondents are male), he was asked how much he paid and how much he received.

ADAM respondents are allowed to report recent purchases by a variety of categories (e.g., bags, capsules and foil packets), but about half reported amounts in grams, ounces or pounds. We converted those responses into gram equivalents and discarded amounts less than one gram and more than one pound.

Arrestees tended to purchase larger quantities of marijuana than did members of households, although the differences were not large. About 36 percent of arrestees bought 1–5 grams compared with 46 to 51 percent of household members. The range for household members results from having to interpolate within categories. About 21 percent of arrestees purchased 5–10 grams compared with 30 to 36 percent of household members. About 43 percent bought more compared with about 19 percent of household members. Arrestees spent more on their purchases. About 36 percent spent $21 or less compared with 52 percent of the household members. About 17 percent spent more than $100 compared with 6 percent of household members.

We estimated a regression with dollar expenditure divided by grams purchased as the dependent variable. Each of the eight ADAM locations was represented by a dummy variable. The amount purchased entered as grams and grams-squared. Time entered in two ways. The first regression represented each year with a dummy variable. The second regression represented included the year minus 2000 (TIMETREND) and the square of year minus 2000 (TIMETREND_SQ). Table 5.8 reports both regressions exclusive of the constant and the site effects.

Table 5.8. Two Regressions with Price per Gram Purchased as the Dependent Variable

	Regression 1			*Regression 2*		
Variables	***Estimate***	***Standard error***	***T-score***	***Estimate***	***Standard error***	***T-score***
GRAMS	-0.085	0.012	-6.880	-0.085	0.013	-6.750
GRAMS_SQ	0.000	0.000	6.300	0.000	0.000	6.150
y2001	0.159	0.457	0.350	0.527	0.285	1.850
y2002	1.005	0.594	1.690	-0.035	0.026	-1.320
y2003	1.208	0.672	1.800			
y2007	1.710	0.789	2.170			
y2008	2.015	0.846	2.380			
y2009	1.906	0.643	2.960			
TIMETREND				0.527	0.285	1.850
TIMETRENDSQ				-0.035	0.026	-1.320
Observations	4452					

A Wald test using results from the first regression shows that prices are not constant across the years (P<0.001). The second regression suggests that prices increase throughout the period (P<0.005). The important point is that the ADAM data provide no evidence that prices have decreased as one might expect if supply had been increasing.

5.3.4 Why Would Prices Increase?

Estimates are not adjusted for changes in the consumer price index, so that might account for some of the upward drift in prices. However, marijuana prices may have been increasing because the quality of marijuana has been increasing. Referring back to the earlier discussion about trends in marijuana potency, the estimates strongly imply that Americans are using more of the active ingredient in marijuana (THC) even if they are not using more marijuana by weight. Of course the availability estimation methodology of dividing eradication by the eradication rate cannot capture improvements in marijuana potency. Possibly, however, the increased potency explains why marijuana prices appear to have increased according to STRIDE data and ADAM data.

This observation raises another concern with methodology. If the quality of marijuana is increasing, this implies that a hectare of marijuana is yielding less marketable marijuana over time. Producers may be increasingly selective regarding the plant products that they bring to market.

5.3.5 Discussion of Price Trends

Three independent sources provide consistent views that marijuana prices have not decreased as would be expected if marijuana supply had expanded. There is some variation from year to year. This could be due to sampling variation, although some of the year-to-year changes appear to be statistically significant. Some of the analysis indicates that marijuana prices have been increasing, perhaps because the quality of marijuana has been improving. The important point is that there is no apparent price decrease that would be commensurate with a large increase in marijuana availability to the United States.

The only way that prices could remain stable when the marijuana supply increases is if the demand for marijuana were also increasing. This would manifest as more marijuana use in the United States. The next section examines trends in marijuana use, showing that marijuana use has been fairly constant.

5.4 Use of Marijuana

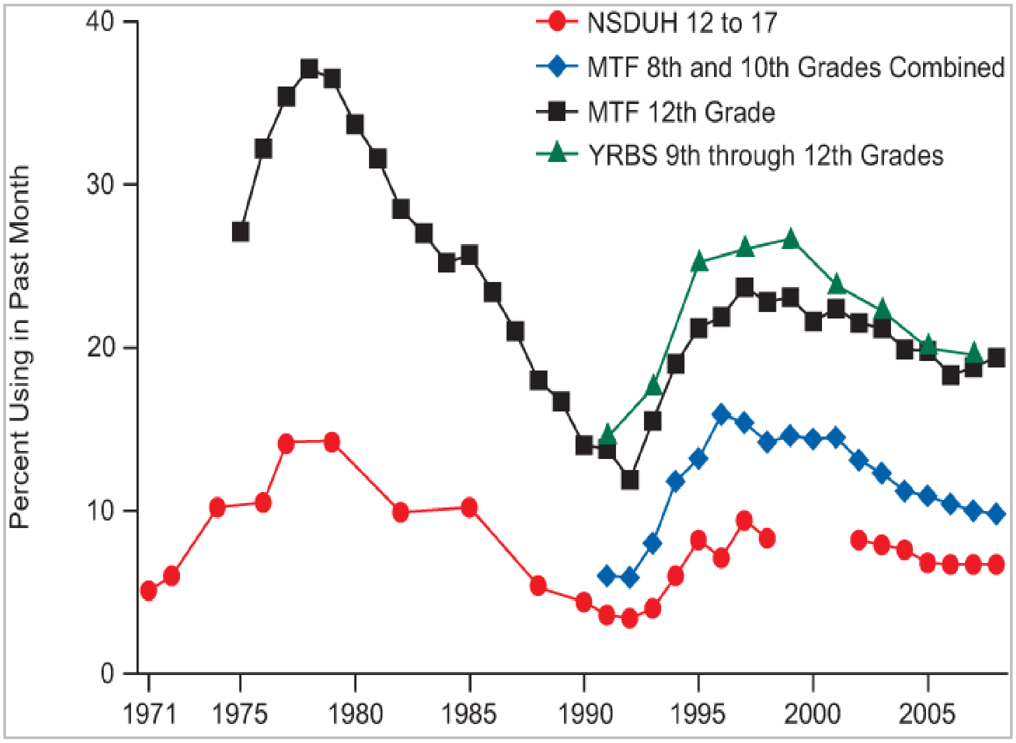
If marijuana had become increasingly available over the last decade, users must have increased their consumption. After all, producers would not continuously increase cultivation to satisfy a market where demand is incommensurate. Survey results indicate that markets are not increasing and may be declining. Evidence comes from multiple sources.

5.4.1 Use by Youth

Figure 5.10 reproduces Figure 5.9 from Results from the *2008 National Survey on Drug Use and Health: National Findings* published by the Office of Applied Studies of the Substance Abuse Mental Health Services Administration.[99] The figure has the advantage of combining data from three sources: the National Survey on Drug Use and Health, the Monitoring the Future survey, and the Youth Risk Behavior Survey.

[99] http://www.oas.samhsa.gov/nsduh/2k8nsduh/2k8Results.cfm#Ch9. Downloaded June 25, 2010.

Figure 5.10. Changes in Youth Marijuana Use



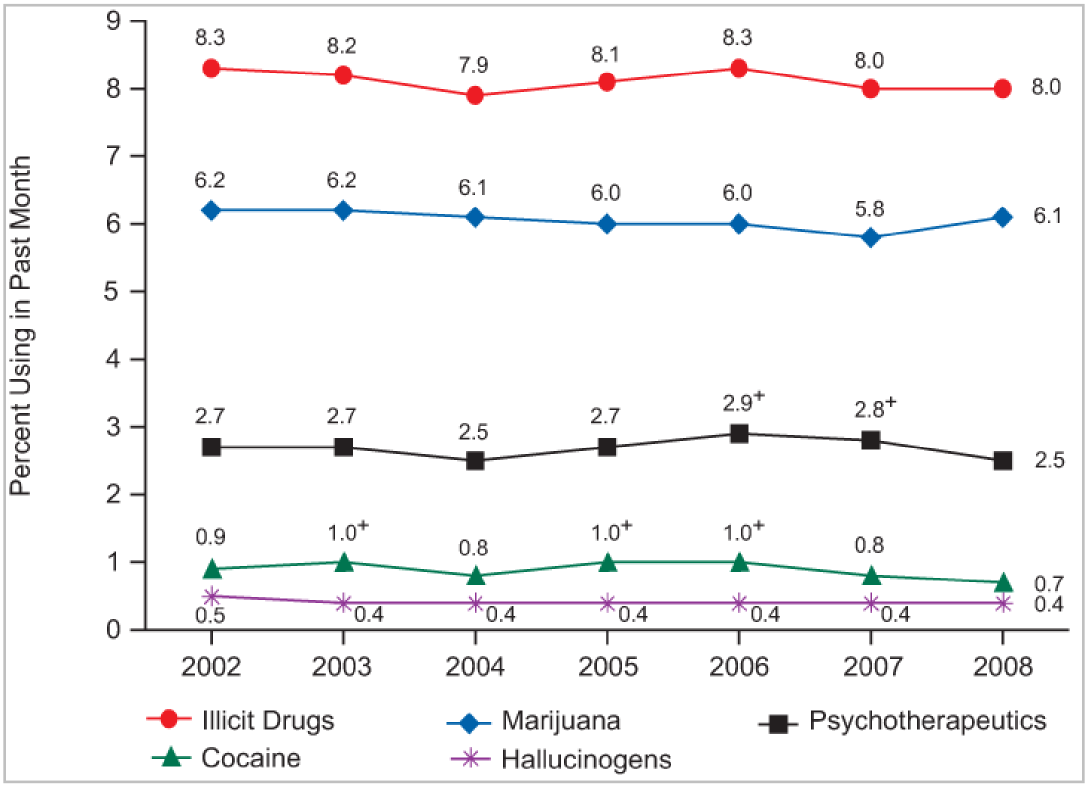
MTF = Monitoring the Future; NSDUH = National Survey on Drug Use and Health; YRBS = Youth Risk Behavior Survey. Note: NSDUH data for youths aged 12 to 17 are not presented for 1999 to 2001 because of design changes in the survey. These design changes preclude direct comparisons of estimates from 2002 to 2008 with estimates prior to 1999.

The figure covers a period extending earlier than the decade of interest to this current report: 2001 through 2008. The evidence is compelling. During the current decade, the NSDUH indicates that use has been fairly flat. The other surveys show a decline. If marijuana production has increased, U.S. youth cannot account for the growth.

5.4.2 Use in the General Population

Figure 5.11 reproduces Figure 2.2 from the same report from the Office of Applied Studies. This figure is based exclusively on NSDUH data and unlike the earlier figure, this one includes all respondents aged 12 and over.

Figure 5.11. Past Month Use of Selected Illicit Drugs among Persons Aged 12 and Older: 2002–2008



Present interest is focused on the percentage of respondents who used marijuana in the last month. The percentage has hovered near 6 percent between 2002 and 2008. Again, there is no evidence that increased production is moving to expanding markets.

One might object that the same number of people uses marijuana but that they use it more frequently because of increased availability. There is some evidence supporting this assertion. The NSDUH asks those who used during the last month how frequently they used during the last month. Based on tabulations from the NSDUH, the frequency of use increases steadily from an average of 12.1 times per month in 2001 to an average of 13.0 times per month in 2008.[100] This 7 percent increase from 2001 to 2008 is consistent with increased availability.

There are two alternative explanations, however. The first is that fewer youth are in the market (see the previous figure), and youth are likely to use less frequently than adults, leaving a residual of comparatively heavy users. The second is that changes to the NSDUH methodology—which has demonstrably improved reporting—may account for some of this change. Even discounting these two explanations, the comparatively small 7 percent increase is inconsistent with a tripling in availability according to the extant estimation methodology.

[100] From 2001 through 2008 the averages are 12.12 (cited in the text), 12.39, 12.43, 12.49, 12.50, 12.60, 12.75 and 13.01 (cited in the text).

5.5 Conclusions

The extant methodology for estimating the amount of marijuana available to the United States lacks credibility. There are three reasons. The first two reasons are logical; the third is empirical. The first reason is that the extant availability model ignores the dynamics of marijuana markets. Interventions that eradicate crops increase the cost of doing business but do not substantially increase the total costs of trafficking. This is because the cost of planting, cultivating and harvesting is a small proportion of the cost of delivering marijuana to buyers. A simple model of supply and demand suggests that even large changes in eradication rates will not greatly reduce marijuana availability to the United States.

The second reason is that the model rests on questionable assumptions and data. Data regarding yields are probably wrong; models that assume constant proportionality between eradication/seizures and potential production are probably incorrect. The problem is that criminals and police have changed their enforcement and business practices. There is little reason to suppose that data about yields have remained constant; there is little reason to suppose that eradication/seizure rates have remained constant. But if the assumptions about constancy of yield and seizure rates are abandoned, there is no reason to assume that the extant methodology can estimate either the amount of marijuana or trends in the availability of marijuana.

The third reason is empirical. Data about marijuana use and marijuana prices are compelling because they are based on highly regarded surveys or because (in the case of STRIDE) the findings agree with the findings from those surveys. There is no evidence that increasing amounts of marijuana have moved to market during the last decade. That additional consumption should be easy to observe; it has not been observed. The most parsimonious explanation is that there had been no increase in the availability of marijuana to the United States.

Is it possible nevertheless to build supply-based models of marijuana availability to the United States? Given the evidence, it appears quixotic to start with production potential and eradication rates. Estimation might begin with seizure rates at the border, but eventually a model based on border seizures will confront validity challenges, and anyway, a model based on border seizures is uninformative about domestic cultivation.

An alternative approach is to return to reasoning based on economic theory. It appears that the demand for marijuana has remained constant during the decade. Tentatively accept that truth of that assertion, recall an earlier note that the elasticity of demand is roughly -0.5.[101] Finally recall from the section on prices that, if anything, prices may have increased.

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[101] An earlier note indicated that Grossman et al. (2001) concluded that a conservative lower bound for marijuana price elasticity is about -0.30 and an upper bound is likely larger than -0.69. Becker et al. (2006) concluded that "…estimates for different drugs generally indicate an elasticity of less than one in absolute value, with a central tendency of about one-half.… " Clement (2005) argues that without better information, a researcher should assume that the elasticity is about -0.5. This advice is consistent with elasticity estimates for alcohol and tobacco.

Perhaps the best price estimates come from the NSDUH because it reaches a representative population of users from across the United States. An analysis of NSDUH purchase data indicated that there was no change in prices, so regardless of the demand elasticity, the conclusions is that the supply of marijuana has remained constant.

Perhaps the second most compelling price estimates come from ADAM. The limitation is that ADAM represents just ten places, unlike the NSDUH, which is a national probability estimate. Also ADAM data are unavailable for 2004 through 2006.

The STRIDE data are the least useful for reasons already explained: DEA rarely makes controlled purchases of marijuana at the street level, and consequently STRIDE data are sparse and may be biased.

An alternative to resting conclusions on the elasticity of demand is to simply focus estimation on demand-based estimates. The National Survey on Drug Use and Health and the Arrestee Drug Abuse Monitoring survey provide good data on purchases and use. Estimation is not free of assumptions, but the assumptions principally affect estimates of the amount of marijuana used at any time. Estimates of trends are not as burdened by assumptions.

Chapter 6: Conclusions

Estimating the prevalence and trends in the availability of illegal drugs to the United States is important for formulating, implementing, and monitoring anti-drug policy. Despite the apparent need for prevalence and trend estimates, data assembly and estimation is daunting and as this report demonstrates, the year-to-year estimates are measured with considerable imprecision. Moreover, the estimates are often inconsistent with other indicators of drug use and availability. Accordingly, this report argues that the data are inadequate to reach conclusions about year-to-year variation in availability and the focus should be on long-term changes in drug availability that can be estimated with greater precision.

Considering estimates for the four major drugs, estimates of the long-term prevalence and trends in *cocaine* availability, as discussed in Chapter 2, may be the most credible. That relative credibility comes not only from the fact that data are carefully assembled but also from the fact that the intelligence services of the United States Government (i.e., CNC) and the United Nations Office on Drugs and Crime provide semi-independent estimates that can be combined to provide a best estimate that is superior to an estimate from a single source. Although estimates from these two sources often disagree when compared for a single year, they provide estimates that appear to agree regarding prevalence and trends over time.[102]

Of the remaining three drugs (heroin, methamphetamine, and marijuana), Chapter 3 argues that estimates of long-term prevalence and trends in *heroin* availability may be the most credible. In addition to the fact that there are no independent estimates from the United Nations, so there is no independent verification, estimates for heroin have two major deficiencies. The first problem is high variability in estimates of hectares of poppy under cultivation. Given the apparent movement of poppy cultivation from Colombia to Mexico, it has undoubtedly been difficult to establish a stable sampling frame for CNC crop estimates, and this instability cannot be factored into standard errors for source area potential production. The spike in 2008 suggests that the sampling frame may have been incomplete for earlier years. The second major problem is the unreliability of estimates from the Heroin Domestic Monitor Program (Rhodes et al., 1998; Manski et al., 2001). Chapter 3 reported three estimates: one based on South and Central American heroin combined, one based on South American heroin alone, and one based on Mexican heroin alone. The three estimates should be the same except for sampling error, but they are not, indicating that (1) potential production estimates are very wrong for South or Central America (or both), or (2) HDMP estimates are very wrong from source area potential production, or (3) both. These data issues need to be resolved to improve the credibility of the heroin estimates.

[102] The divergent year-by-year estimates appear to arise from sampling errors that go well beyond the error attributable to sampling design.

Availability estimates for *methamphetamine* are encouraging, but there is a major problem identified in Chapter 4. The best estimates for methamphetamine are anchored in years when credible estimates of the availability of precursor chemicals existed. With the implementation of restricted controls on precursor chemicals, however, an analyst's ability to update equivalent estimates for the anchor years has disappeared. Thus, the methodology employed for past estimates is unavailable moving forward and future estimates of methamphetamine availability will need to rely on innovative estimation methods. For example, one might draw inferences from border seizures (as small labs and super labs play an increasingly subordinate role in methamphetamine production) and trends in consumption.

As discussed in Chapter 5, deriving availability estimates for *marijuana* is truly a challenge. As the National Drug Intelligence Center concluded, there is currently no methodology for making inferences. The best data reflecting production—Mexican potential production, border seizures, and domestic crop eradication—are so inconsistent with what appear to be reliable consumption data based on the National Survey on Drug Use and Health and the Arrestee Drug Abuse Monitoring survey that these potential production data are not credible.

There is a clear need for reliable availability estimates, so the question is: How can ONDCP move from the current state of the science to an improved state of the science? This report argues that advancing the estimation of prevalence and trends in drug use will come from ***improved data collection and improved modeling***. Some suggestions follow:

In some instances, the available data are inadequate for developing credible estimates. For example, the estimates from the HDMP appear to be flawed. Unfortunately, HDMP data are crucial to the heroin availability estimates. ***The sampling problems with the HDMP should be resolved to ensure these data are useful for providing reliable estimates***. This resolution is feasible as cited by others (e.g., Rhodes et al., 1998; Manski et al., 2001). This suggestion relates to other data (referenced throughout the report) used in the estimation of the availability of illicit drugs in the United States.

Similarly, the documentation of data sources and methodologies used by the U.S. Government to derive estimates that are crucial for subsequent availability estimates is limited. One reason for this report is to document sources that are not documented elsewhere, but methodology changes periodically and documentation does not always keep pace. Often the source of data of the government estimates (e.g., potential production estimates) is not clear. Moreover, the methodologies used to derive estimates are infrequently provided in written format and when they are, they often lack important details, such as details on sampling plans and methods for dealing with missing data. The government estimates are frequently reported in PowerPoint presentations that report findings and have limited critical assessment of the methods used. ***Arguably, enhanced Government documentation of source data and estimation methodologies would lead to improved estimates.***

Moreover, even with the best data, this report has argued that the accounting methodology is inadequate for estimating availability and that ***availability estimates should be embedded in an economic model of market behaviors.*** This is not to argue that the simple economic model adopted for this report is correct in all respects. It is to argue, as stated above, that the data and methodology must be improved in order to improve the estimation.

One important implication of resting estimates on an economic model is the adoption of a more realistic view that potential production moves more slowly to market, rather than the current approach of deriving availability estimations from yearly reports of potential production that are implicitly assumed to affect U.S. consumption during the same year. This need not imply that high-level dealers warehouse product, but merely that they require time to move drugs, arrange purchases, and transport the product from seller to buyer. It seems likely that this movement is accelerated when drugs are in relatively short supply and that the movement is slowed when drugs are relatively abundant. Given the high degree of uncertainty regarding estimates for any single year and the market incentives to vary the delivery pace, examining long-term trends seems preferable to examining year-by-year differences.

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Appendix A.
Technical Appendix: Heroin Estimates

A1. Details for Opium Yield Calculations

The total volume of the mature capsules in each subsample, CVOLs (cm3) is calculated from the heights and diameters of individual capsules using the following equation ($V_{sphere}=4/3\pi r^3$):

$$CVOLs = \Sigma(4/3 * \pi * a^2 * b)$$

where, a = half the capsule diameter (cm), b = half the capsule height (cm).

An average mature capsule volume is calculated:

$$MNVOL = CVOLs / ns$$

where, ns = number of mature capsules measured.

Projected capsule volume for the sample at the end of harvest, CVOL (cm3 m-2) is calculated using the equation:

$$CVOL = (FB + F + Ci + Co + Cm) * MNVOL$$

where, FB = number of flower buds counted in the one-meter-square sample
F = number of flowers in the sample
Ci = number of immature capsules in the sample
Co = number of missing capsules in the sample
Cm = number of mature capsules in the sample

The non-rectangular hyperbola equation used to estimate oven-dry opium yield, Y (kilograms ha-1) from projected capsule volume is:

$$Y = [(CVOL + b) - ((CVOL + b)2 - 4 * a * c * CVOL) 0.5] / [2 * c]$$

where a = 110.1, b = 1495, and c = 0.8975.

A2. Heroin Seizure Data

The estimation methodology described in this section requires estimates of seizures of heroin by source area. However, the data available, principally from DEA's FDSS and HSP, do not directly supply this information. While FDSS data identify seizures by drug type, they do not identify the source county. Meanwhile, although the heroin seizures included in the HSP do indicate the source country, the HSP comprises only a subset of all U.S. heroin seizures. This technical appendix outlines the procedure by which the heroin availability estimates were developed using HSP data to estimate the proportion of FDSS seizures by source country.

Data Sources for Heroin Seizures

The process for estimating the availability of heroin in the United States detailed previously uses the estimated amount of heroin seized (both in bulk and pure amounts) by source country as its foundation. The process focuses on heroin from Mexico and South America, primarily because these two heroin-producing countries make up the bulk of the supply of heroin that is eventually available in the United States. Estimates of seizures of heroin identified by country of origin are calculated by bringing together two distinct data sources: FDSS and HSP. The HSP data are used to augment FDSS data; however, all of the final estimates of supply and availability are calculated using FDSS as the final data source.

Computing Seizures from the FDSS

The bulk total amount of heroin that is seized for each year from 2001 to 2006 is calculated using FDSS. Table A.1 below shows the results of these calculations.

Table A.1. Total Heroin Seized in the United States, by Year (Metric Tons)

Year	*Total Heroin Seized*
2001	2.47
2002	2.75
2003	2.36
2004	2.11
2005	1.72
2006	1.75

The data depicted in Table A.1, however, do not provide information regarding (a) the proportion of total heroin that was imported from Mexico, (b) the proportion that was imported from South America, or (c) the amount of pure heroin that these bulk numbers represent—all of which are crucial elements in developing and completing the model of heroin availability. Thus, HSP data are leveraged to supplement the total numbers with the necessary information.

Augmenting FDSS Data with HSP Distributions

HSP is a useful tool for assessing the purity and source of origin of heroin seized in the United States. Because HSP data comprise arrival zone seizures of heroin included in the larger DEA STRIDE data set, it is reasonable to assume that the source country distribution of seizures in the HSP should approximate the distribution of seizures in the FDSS. Operating on that principle, calculations are developed using HSP data and applied to FDSS using the methods described below.

First, to derive the total amount of seizures by source (*D*) and the purity of imported heroin by source (*E*) of the heroin model, the HSP data are used to compute the following:

- The total amount of Mexican heroin seized for each year (D_{MX}),
- The total amount of South American heroin seized for each year (D_{SA}),
- The (weighted) average purity of Mexican heroin seized (E_{MX}), and
- The (weighted) average purity of South American heroin seized (E_{SA})

Also, because it is known that border seizures of heroin are likely to be markedly different from domestic seizures of heroin in terms of seizure size and purity, the measures of D and E are further broken down to reflect the border/non-border composition of seizures, as shown below. For these equations, D^B represents total amount of heroin seized at the border, and D^{NB} represents total amount of heroin seized within the United States. Therefore,

let, t = each year from 2001 – 2006 and,
source country j = {MX, SA}

such that,

[1] $D_{jt} = D_{jt}^{B} + D_{jt}^{NB}$, and

[2] $$E_{jt} = \left(\frac{D_{jt}^{B}}{D_{jt}^{B} + D_{jt}^{NB}}\right)E_{jt}^{B} + \left(\frac{D_{jt}^{NB}}{D_{jt}^{B} + D_{jt}^{NB}}\right)E_{jt}^{NB}$$

Equation [1] is the total amount of seizures by source and year, and equation [2] is the average purity of seizures by source and year.

Since neither source country nor purity information is captured in FDSS, D_{jt} or E_{jt} cannot be computed using FDSS alone. Instead, the FDSS seizure totals (depicted in Table 1) are modified to reflect the source country distribution and associated purities using observations from HSP.

(1) Total Amount of Heroin Seized (D)

First, to compute D_{jt}:

Let, $FDSS_t$ = the FDSS reported amount of total heroin seized in year (t) (from Table 1),

S_{ijt}^{B} = bulk seizure amount for the i^{th} observation in HSP, from source country (j), in year (t) seizure, at the border,

S_{ijt}^{NB} = seizure amount for the i^{th} observation in HSP, from source country (j), in year (t) seizure, within the U.S,

T_t = the **total** amount of heroin seized (both at the border and within the United States) among all source countries in a given year (t), according to HSP,

P_{jt}^{B} = proportion of total seized heroin (*T*) that is from source country (*j*) seized at the border in year (*t*),

P_{jt}^{NB} = proportion of total seized heroin (*T*) that is from source country (*j*) seized within the United States in year (*t*),

where,

$$[3] \quad T_t = \sum_{j=1}^{J}\sum_{i=1}^{N} S_{ijt}^{B} + \sum_{j=1}^{J}\sum_{i=1}^{N} S_{ijt}^{NB}$$

$$[4] \quad P_{jt}^{B} = \sum_{i=1}^{N} \frac{S_{ijt}^{B}}{T}$$, for each (*j*) = {MX, SA} and (*t*) = {2001, 2002…2006}, and

$$[5] \quad P_{jt}^{NB} = \sum_{i=1}^{N} \frac{S_{ijt}^{NB}}{T}$$ for each (*j*) = {MX, SA} and (*t*) = 2001, 2002…2006},

such that,

$$[6] \quad D_{jt}^{B} = (FDSS_t) * P_{jt}^{B},$$

$$[7] \quad D_{jt}^{NB} = (FDSS_t) * P_{jt}^{NB}$$, and

$$[8] \quad D_{jt} = D_{jt}^{B} + D_{jt}^{NB}$$

Table A.2 below shows the calculations of P_{jt}^{B} , P_{jt}^{NB} , $FDSS_t$, D_{jt}^{B} and D_{jt}^{NB} using HSP data.

Table A.2. Estimated Seizure Total and Proportions, by Source Country, and Border/Non-Border Seizure Type (Metric Tons)

		Mexico					South America				
Year	**FDSS**	P^{B}	P^{NB}	D^{B}	D^{NB}	**D**	P^{B}	P^{NB}	D^{B}	D^{NB}	**D**
2001	2.47	20.0%	10.0%	0.49	0.25	0.74	46.4%	9.5%	1.15	0.23	1.38
2002	2.75	4.6%	5.3%	0.13	0.15	0.27	63.4%	15.0%	1.74	0.41	2.15
2003	2.36	1.3%	1.9%	0.03	0.05	0.08	59.3%	27.2%	1.40	0.64	2.04
2004	2.11	10.1%	4.3%	0.21	0.09	0.30	48.0%	20.6%	1.01	0.43	1.45
2005	1.72	11.8%	2.1%	0.20	0.04	0.24	45.2%	22.3%	0.77	0.38	1.16
2006	1.75	18.7%	2.4%	0.33	0.04	0.37	48.6%	24.5%	0.85	0.43	1.28

(2) ***Weighted Purity of Heroin Seized (E)***

Recall the equation [2] for calculating purity mentioned above:

$$E_{jt} = \left(\frac{D^B_{jt}}{D^B_{jt} + D^{NB}_{jt}} \right) E^B_{jt} + \left(\frac{D^{NB}_{jt}}{D^B_{jt} + D^{NB}_{jt}} \right) E^{NB}_{jt}$$

As part (1) showed, HSP is already used to calculate D^B_{jt} and D^{NB}_{jt}. All that remains in order to compute E_{jt} is to use the HSP to determine purity by seizure location (border vs. non-border). Fortunately, determining E^B_{jt} and E^{NB}_{jt} is a straightforward calculation. First,

Let, S^B_{ijt} = **bulk** seized amount for the *i*^*th* observation in HSP, from source country (*j*), in year (*t*) seizure, at the border,

S^{NB}_{ijt} = **bulk** seized amount for the *i*^*th* observation in HSP, from source country (*j*), in year (*t*) seizure*,* within the U.S,

H^B_{ijt} = **pure** seized amount for the *i*^*th* observation in HSP, from source country (*j*), in year (*t*) seizure, at the border,

H^{NB}_{ijt} = **pure s**eized amount for the *i*^*th* observation in HSP, from source country (*j*), in year (*t*) seizure*,* within the United States,

such that,

[8] $$E^B_{jt} = \frac{\sum_{i=1}^{N} H^B_{ijt}}{\sum_{i=1}^{N} S^B_{ijt}}$$ for each (*j*) = {MX, SA} and (*t*) = {2001, 2002…2006}, and

[9] $$E^{NB}_{jt} = \frac{\sum_{i=1}^{N} H^{NB}_{ijt}}{\sum_{i=1}^{N} S^{NB}_{ijt}}$$ for each (*j*) = {MX, SA} and (*t*) = {2001, 2002…2006},

Summing the **pure** and **bulk** seizure amounts as shown above ensures a self-weighted measure of purity, where the purity of larger seizures receive proportionally more weight in the overall purity measure. Table A.3 below shows the average purities of border and non-border seizures calculated in HSP, by source country.

Table A.3. Estimated Purity of Border/Non-Border Seizures, by Source Country

	Mexico					South America				
Year	E^B	E^{NB}	D^B	D^{NB}	E	E^B	E^{NB}	D^B	D^{NB}	E
2001	18.0%	14.1%	0.49	0.25	16.7%	80.1%	75.3%	1.15	0.23	79.3%
2002	39.2%	20.7%	0.13	0.15	29.3%	79.1%	78.5%	1.74	0.41	79.0%
2003	47.4%	35.8%	0.03	0.05	40.4%	75.4%	76.5%	1.40	0.64	75.8%
2004	24.4%	26.6%	0.21	0.09	25.1%	73.7%	88.9%	1.01	0.43	78.3%
2005	39.1%	46.8%	0.20	0.04	40.2%	72.1%	60.8%	0.77	0.38	68.4%
2006	40.6%	27.7%	0.33	0.04	39.1%	67.1%	76.4%	0.85	0.43	70.2%

Appendix B. Technical Appendix: Methamphetamine Estimates

B1. STRIDE-FDSS Purity Matching Algorithm

This section of the appendix provides a step-by-step explanation of how information on methamphetamine seizures taken from the DEA STRIDE data set was used to augment information about methamphetamine seizures taken from the FDSS data set.

In measuring the annual total amount of methamphetamine that is seized domestically, FDSS serves as the primary source of information from which estimates are derived. Though FDSS provides aggregate statistics on Federal drug seizures made within U.S. jurisdictions, it does not report the purity of the methamphetamine being seized. In order to convert FDSS-reported bulk seizure weights to pure amounts, it is necessary to impute purity information from the STRIDE data set to supplement FDSS.

The STRIDE data set allows the identification of the same characteristics of individual seizures as in the FDSS, i.e., date, state, quantity, and the Federal Drug Identification Number (FDIN) associated with each seizure. Normally, the FDIN would be used to match seizure and purity information between these two data sources; however, the FDIN alone does not provide a unique link between these sources. The table illustrates this point using examples.

FDSS				STRIDE			
FDIN	**Date**	**State**	**Quantity**	**FDIN**	**Date**	**State**	**Quantity**
2004013475	10/30/2003	OR	1203	2004013475	10/30/2003	HI	27.2
				2004013475	10/30/2003	HI	111.6
				2004013475	10/30/2003	OR	402.2
				2004013475	10/30/2003	OR	800.5
2005132737	08/25/2005	IN	453	2005132737	08/25/2005	AL	4.8
				2005132737	08/25/2005	AZ	< 0.1
				2005132737	08/25/2005	FL	< 0.1
				2005132737	08/25/2005	FL	< 0.1
				2005132737	08/25/2005	GA	20.1
				2005132737	08/25/2005	TX	3.0
				2005132737	08/25/2005	WV	< 0.1
				2005132737	08/25/2005	WV	1.2
2003015597	11/08/2002	WA	365	2003015597	11/10/2002	IA	42.8
				2003015597	11/09/2002	IN	2.2
				2003015597	11/09/2002	TN	< 0.1
				2003015597	11/08/2002	TX	24.0
				2003015597	11/08/2002	TX	9.7
				2003015597	11/08/2002	VA	< 0.1
				2003015597	11/08/2002	VA	0.1
				2003015597	11/09/2002	VA	< 0.1
				2003015597	11/09/2002	VA	1.8

As a result, other data elements, specifically seizure **date**, **state,** and **quantity**, are used to create an algorithm for matching/mapping purity information between the FDSS and STRIDE data sets. Though these reported elements are common to both FDSS and STRIDE, there remain many discrepancies that make matching and linking between these data sources an imperfect process.

Step 1—Linking one-to-one observations

First, instances were identified where there was only **one FDSS** seizure record for a particular state and day. Next were identified instances where there was only **one STRIDE** seizure record for a particular state and day. Where these individual records matched by state and day, regardless of their reported quantities, the purity value was assigned from the associated STRIDE observation to the corresponding observation in FDSS. Essentially, the process assumes that the sample represented in STRIDE for that state and day either 1) is a sample from the methamphetamine seizure depicted in the FDSS or 2) represents the best approximation of the probable characteristics of the methamphetamine seizure described for that day in that state.

Step 2—Linking multiple observations

Next, we identified remaining unmatched instances where one or multiple FDSS seizure records for each state and day *could be linked* to one or multiple STRIDE records for that state and day. Unlike Step 1, quantity measures (rather than date and state alone) were used as the means for differentiating which STRIDE observations best corresponded to the FDSS observation for that state and day. As such, each of the seizure amounts reported in STRIDE observations were compared with corresponding observations in FDSS. Where the difference between these reported weights was less than or equal to **± 1 gram**, the seizure records were considered to be a match and the purity value from the associated STRIDE observation was assigned to the corresponding observation in FDSS.[103]

After steps 1 and 2 have been completed, each of the remaining unmatched records in FDSS can be classified into one of two categories: (1) an FDSS state-day record with *no* corresponding STRIDE records or (2) an FDSS state-day record with one or multiple corresponding STRIDE records, *none* of which match on seizure amount. Every record that falls into category (1) is set aside in a group that to be addressed in step 5. Every observation that is part of category (2) will be addressed in the next step.

Step 3—Average state-day purity by day, by weight group

Although the records in category (2) described above do not perfectly match on seizure amount, the best approximation of the expected purity for each state-day record remains the average purity of drugs seized for that state and day where the seizure weight are similar even if they are not exactly the same. To this end, weight groupings for each seizure in the FDSS and STRIDE data sets are defined as follows:

- Weight class A = $q < 1g$,
- Weight class B = $1000g > q \geq 1g$,
- Weight class C = $4500g > q \geq 1000g$, and
- Weight class D = $q \geq 4500g$,

where q is the reported quantity seized. A weighted average of purity (proportional to seizure weight) is calculated for each state-day-weight class reported in STRIDE and these purities are matched to related state-day-weight class records in FDSS.

Step 4—Average state-day purity by day, ignoring weight group

There are instances where FDSS state-day records cannot be matched to STRIDE state-day records because there is no matching weight class. Again, it is assumed that the best approximation of the expected purity for each state-day record is the average purity of drugs seized for that state and day, even where the reported weight class of the seizures differs. To that end, a weighted average of purity (proportional to seizure weight) for each set of state-day records in STRIDE is calculated and these purities are matched to related state-day records in FDSS. At the end of these four steps,

[103] Where there are multiple STRIDE records that meet this criterion, a weighted average of the purity is used to determine the purity associated with the FDSS record.

those observations that remain unmatched to purity information in STRIDE are those records for which there are no corresponding state-day records in STRIDE, i.e., category (1) described earlier. One complication with this matching is that reported seizure weights within STRIDE may sometimes reflect the size of the sample of methamphetamine sent for analysis, rather than the size of the actual seizure from which it was retrieved. If so, then the reported purity for "small seizures" in STRIDE may in fact be describing the purity of larger seizures of methamphetamine. This mislabeling of purity could affect the accuracy of our estimates of purity, particularly if seizure size is strongly correlated with purity.

Step 5—Predicting purity for state-day records

For those records in FDSS with no corresponding state-day information in STRIDE, the information in the "matched" portion of FDSS is used to estimate the purity for the remaining "unmatched" FDSS records. A reasonable solution to estimating these purities would be to take a weighted average of all FDSS recorded seizures and imputed purities within a given year, state, and weight class, and apply that estimation to each remaining FDSS record in that state, year, and weight class—similar to what is done in step 3.

However, as noted at the end of Step 4, the purity estimates of smaller seizures in FDSS may be somewhat biased by the mislabeling of small samples (from large seizures) in STRIDE. Thus, the approach used instead is to estimate a regression for each weight class that predicts the purity of a seizure as a function of the state, year and a monthly measure of the proportion of labs seizures made where the production capacity of the lab was less than 2 ounces. This model is expressed as:

(1) $$Purity_{ijmy} = \sum_{j=1}^{J} \beta_s (State_s) + \sum_{y=1}^{Y} \beta_y (Year_y) + \beta_L (pctLabs_{jmy}) + \alpha$$

where,

Purity$_{ijmy}$ is the reported purity of the i^{th} record in STRIDE, located in the j^{th} state, during month (*m*) and year (*y*),

State$_j$ is an indicator variable for the j^{th} state,

Year$_y$ is an indicator variable for year (*y*), and

pctLabs is the monthly proportion of labs seizures made where the production capacity of the lab was less than 2 ounces in the j^{th} state, during month (*m*) and year (*y*).

Including aggregated measures of lab capacity in these regressions allows us to at least partially correct for inflated purity figures for small seizures that arise from Step 4. Obtaining these parameter estimates allows the prediction of the average purity for each FDSS record, provided the predicted coefficients are significantly different from zero. For estimates where the coefficients are not significantly different from zero, the coefficients are treated as zero. Once average purity for each remaining FDSS record is predicted, a measure of purity for every record in FDSS is obtainable.

Table B.1 below summarizes each of the steps just described as well as how many observations are matched according to each step.

Table B.1. Summary of Matching Process and Results for Methamphetamine

Step	Description/method	# of obs. matched (5,428 total)	Weight class			
			A	B	C	D
#1	1-to-1 matching of single obs. in both data sets, by state and day	1,792 (33.0 %)	73 (1.3 %)	1,035 (19.1 %)	518 (9.5 %)	166 (3.1 %)
#2	1-to-1 matching of obs. between data sets, by state, day and actual weight	616 (11.4 %)	0 (0.0 %)	325 (6.0 %)	233 (4.3 %)	58 (1.1 %)
#3	Ave. purity matching by state, day, and weight class	1,821 (33.6 %)	0 (0.0 %)	1,154 (21.3 %)	521 (9.6 %)	146 (2.7 %)
#4	Ave. purity matching by state and day, *ignoring* weight class	355 (6.5 %)	0 (0.0 %)	187 (3.5 %)	117 (2.2 %)	51 (0.9 %)
#5	Predicted purity, from a regression of matched FDSS purity on state, year and monthly percent of small labs seized.	844 (15.5 %)	0 (0.0 %)	629 (11.6 %)	147 (2.7 %)	68 (1.3 %)

B2. Deriving a Consumption Trend for Method 2

This section of the appendix describes how the consumption trend used in method 2 to project the change in availability of methamphetamine (starting in 2004) was derived.

Quest Diagnostics provides laboratory services for physicians and medical facilities. As part of its practice, Quest also provides urine testing for drug use for private and public sector employers who contract for this service. Quest data from January 2002 through June 2007 were analyzed to determine what Quest data can tell us about trends in methamphetamine use over this 5-year period. Specifically, we estimate (*i* x *j*) regressions of the following form:

$$E[P_{ijkt}] = N_{ijkt} e^{u_{ijk} + T_{ijkt}\delta_{ij1} + T_{ijkt}^2\delta_{ij2} + T_{ijkt}^3\delta_{ij3} + N_{ijkt}\alpha_{ij} + \gamma_{ij1}\cos t(2\pi T_{ijkt}) + \gamma_{ij2}\sin t(2\pi T_{ijkt}) + \gamma_{ij3}\cos t(\pi T_{ijkt}) + \gamma_{ij4}\cos t(\pi T_{ijkt})}$$

where:

$E[P_{ijkt}]$ is the expected value of the number of positive tests for the i^{th} industry given the j^{th} testing method in zip code *k* at time *t*.

N_{ijkt} is the number of tests for the i^{th} industry given the j^{th} testing method in zip code *k* at time *t*, and

$Tijkt$ is time coded as the month, with the first month being equal to zero, and each month incremented by (1/12). Thus the first year begins with T = 0, the second year begins with T = 1, and so on.

The parameters in this model vary with the industry, testing method, and (for the fixed effect μ) zip code. In fact, separate models are estimated for each industry and testing method (random testing and pre-employment testing only). Conditional on the industry and testing method, each zip code location has a unique effect captured by μ.

Trends are modeled using a polynomial, which is captured by the δ parameters. The polynomial allows the trend to increase or decrease monotonically; it allows the trend to increase and then decrease, or to decrease and then increase. In addition, the polynomial also allows the trend to 1) increase, decrease, then increase again or 2) decrease, increase, then decrease again. This flexibility comes at a price because the polynomial can be inaccurate at the extreme of the time-series.

Cyclical patterns are modeled with the cosine and sine terms. These are known as Fourier transformation. The first sine and cosine terms include the argument $2\pi T_{ijkt}$. Taken together, these two terms allow for a yearly cycle. The second sine and cosine terms include the argument πT_{ijkt}. Taken together, these two terms allow for half-year cycles. The yearly and half-yearly cycles are intended as a flexible way to capture seasonality.

The number of tests (N_{ijkt}) appears twice in this model. First the model includes N_{ijkt} multiplied by an exponential. This allows for a scale effect. Other things equal, we would expect the number of positive urine tests to increase proportionally with the number if urine tests. The model includes N_{ijkt} within the exponential. As explained earlier, this is intended to capture any systematic variation between the probability that a urine test is positive and the number of urine tests performed.

Treating μ as a fixed effect, this conditional Poisson model is estimated 22 separate times (once for each industry and testing method). Once estimates of the δ parameters are obtained, we evaluate the term $\hat{C} = e^{T_{ijkt}\delta_{ij1}+T_{ijkt}^2\delta_{ij2}+T_{ijkt}^3\delta_{ij3}}$ for each regression for each year (using 01/02 as the baseline reference month and year, such that $e^{(0)} = 1$). Then, for each year, a weighted average is taken of the predicted values of $\hat{C}$, where the weights are determined by the proportion of total tests that occurred in i^{th} industry given the j^{th} testing method in zip code k. Taking this weighted average of $\hat{C}$ for each year, gives an estimate of the trend (i.e., the change) in consumption of amphetamines for each year.