Estimation of Heroin Availability

1996-2000

Executive Office of the President
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The Estimation of Heroin Availability: 1996-2000

Prepared for:
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Disclaimer

Information presented in this publication reflects the views of the authors and does not necessarily reflect the official policy or position of the Federal Government. The cut-off date for data used in this report is June 30, 2001.

Executive Summary

This study was commissioned by the Office of National Drug Control Policy (ONDCP) to:

- Provide a baseline for evaluating progress in achieving the supply reduction goals of the National Drug Control Strategy; and
- Inform policy decisions by providing insight into the source of heroin supplying U.S. markets, where it is entering the U.S., and how successful U.S. law enforcement is at detecting and seizing it.

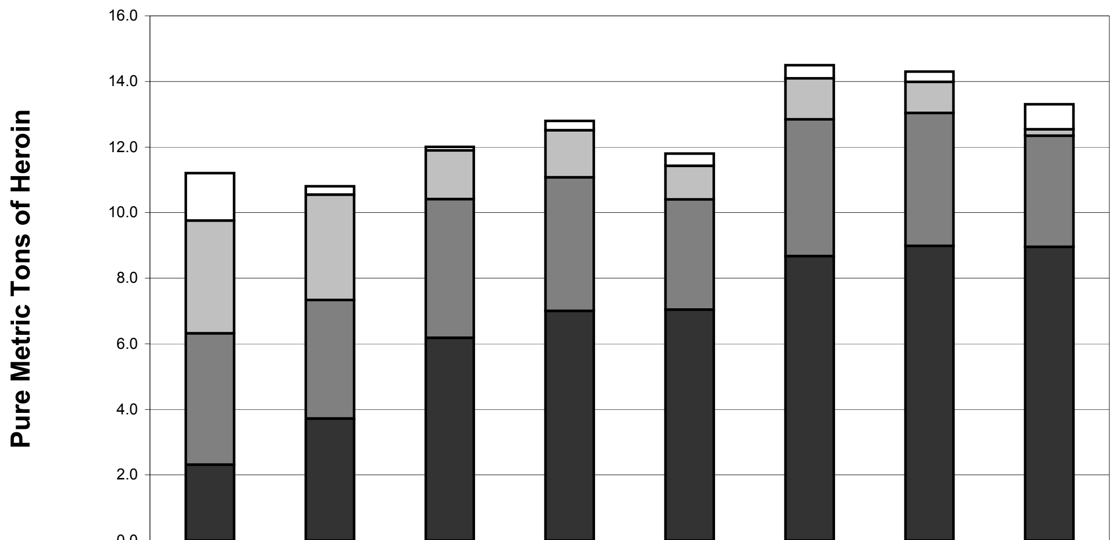
This study updates and extends the analysis done for this report's predecessor *Estimation of Heroin Availability, 1995-1998* (Rhodes, 2000). It seeks to weave together and reconcile information currently known about heroin consumption, heroin seizures and purchases, the source area of heroin seizures and purchases, and heroin production estimates. The end product provides valuable insight into the movement of heroin from various source areas (Mexico, South America, Southeast Asia and Southwest Asia) into and through the United States.

U.S. Consumption of Heroin

It is estimated that Americans have consumed from between 11 to 14 metric tons of heroin per year since 1993.[1] As illustrated in Figure 1, an analysis of retail heroin signature data indicates that South American heroin dominates the U.S. heroin market, particularly in the eastern U.S., accounting for more than 67 percent of the heroin consumed in the U.S. Mexican heroin makes up the second largest share, supplying one-quarter of the U.S.'s heroin consumption. Southeast and Southwest Asia provide the remaining supply of heroin for U.S. consumers with about 2 percent and 6 percent of the market share, respectively. The dominance of South American heroin has steadily increased over the last five years, largely at the expense of Southeast Asian heroin. Eastern U.S. cities are the largest consumers of South American heroin, but its use in other American cities has been steadily increasing over the years. Consumption of Mexican heroin has remained fairly constant over the years with western U.S. cities making up the bulk of its consumer market. Following a sharp decline in 1994, consumption of Southwest Asian heroin appears to be increasing.

[1] Rhodes, W., Layne, M., Bruen A., Johnston, P., and Becchetti, L., *What America's Users Spend on Illegal Drugs 1988 – 2000*. Report prepared for the Office of National Drug Control Policy. Abt Associates Inc., December 2001.

Figure 1 - U.S. Consumption of Heroin by Source Area (CY 1993 through CY 2000)



	1993	1994	1995	1996	1997	1998	1999	2000
SW Asia	1.4	0.2	0.1	0.3	0.4	0.4	0.3	0.8
SE Asia	3.4	3.2	1.5	1.4	1.0	1.2	0.9	0.2
Mexico	4.0	3.6	4.2	4.1	3.4	4.2	4.1	3.4
S. America	2.3	3.7	6.2	7.0	7.0	8.7	9.0	9.0

The Flow of Heroin into the U.S.

The map in Figure 2 illustrates the flow of heroin from each source area into the U.S. through various import regions in Calendar Year 2000.[2] The Southeast U.S. is the preferred import region for South American heroin. This is not surprising when one considers the proximity of this region to South America and the availability of direct commercial airline flights from Colombia to Miami. Since South American heroin makes up two-thirds of our nation's heroin supply, this also gives the Southeast U.S. the distinction of being the primary importation region for *all* heroin entering the U.S. In fact, 40 percent of the heroin entering the U.S. (or 5.72 pure metric tons) does so through the Southeast U.S.

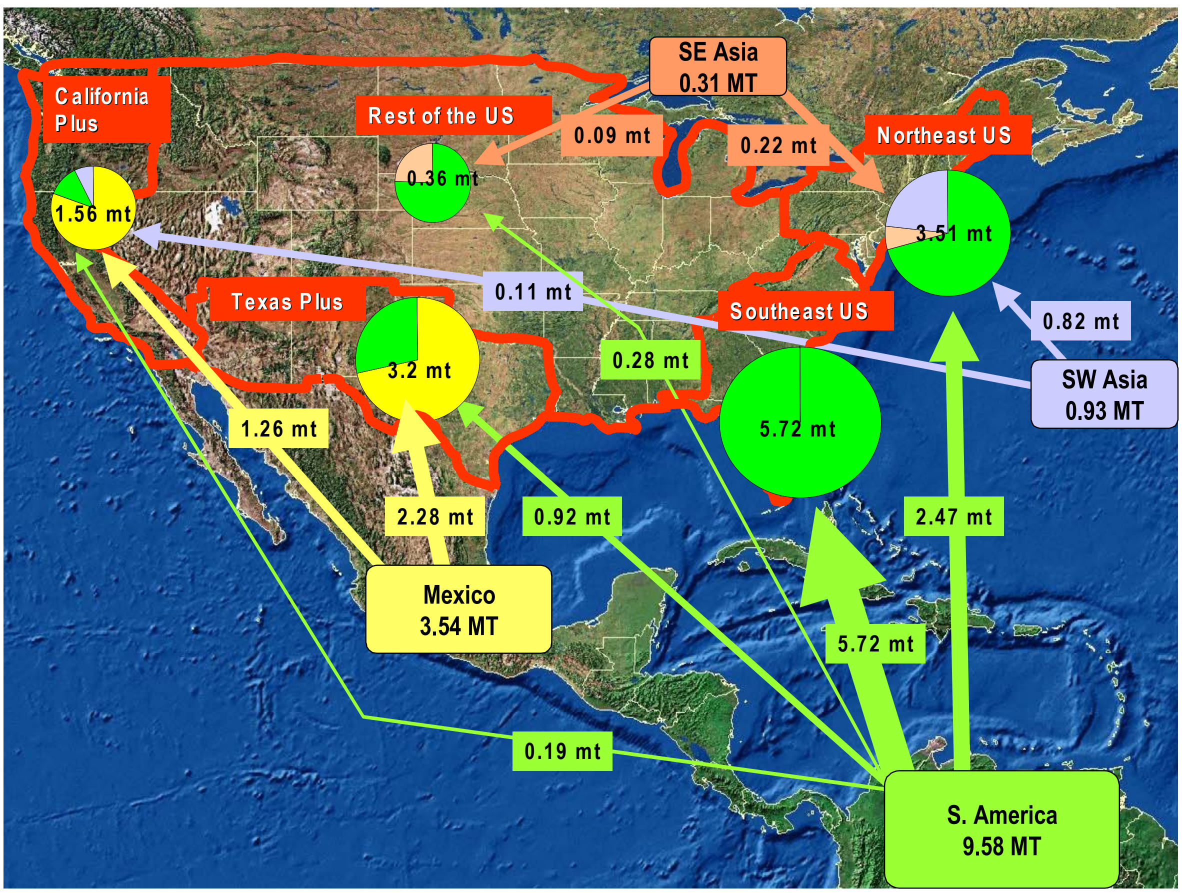
About one quarter of the heroin entering the U.S. comes through the Northeast U.S. The majority of Asian heroin enters the U.S. through the Northeast region. Although Asian heroin comprises less

[2] For purposes of this study, we partitioned the continental U.S. into five geographic areas: Northeast U.S. (which includes the states of CT, DC, DE, MA, ME, MD, NH, NJ, NY PA, RI and VT); Southeast U.S. (FL, NC, SC, VA, GA); TexasPlus (TX, NM, AZ); CaliforniaPlus (CA, OR, WA); and the Rest of the U.S. (all other states).

than 10 percent of the total flow, it accounts for over a quarter of the flow through the Northeast.

Slightly less than one quarter (22%) of the heroin flow enters the U.S. through the TexasPlus region. The majority of this heroin is Mexican, but more than a quarter is from South America. Only eleven percent (1.56 metric tons) of heroin entering the U.S. comes through the CaliforniaPlus region. The majority of the flow into this region is Mexican heroin; relatively small amounts of South American and Southwest Asian heroin enters the U.S. through the CaliforniaPlus region. The Rest of the U.S. accounts for the remaining 3 percent (0.36 metric tons) of the heroin flowing across our borders; comprised largely of South American heroin with small amounts of Southeast Asian heroin.

Figure 2 - The Flow of Heroin From Source Areas Into the U.S. - CY 2000



The following table shows annual trends in the distribution of heroin into the U.S. through the various import areas from 1996 to 2000. Mexican heroin has consistently moved into the U.S. through the CaliforniaPlus and TexasPlus regions. The Northeast U.S. and Southeast U.S. have been the primary import areas for South American heroin, with a trend towards more imports flowing through the Southeast. The TexasPlus region has also increased in importance as an importation region for South American heroin. The Northeast U.S. has been the preferred importation region for both forms of Asian heroin, with the Rest of the U.S. being the second preferred region of entry.

Table 1 - Distribution of Flow from Source Areas into the U.S.

Source Area	Import Region	1996	1997	1998	1999	2000
Mexico	Northeast US	0%	0%	0%	0%	0%
	Southeast US	0%	0%	0%	1%	0%
	TexasPlus	54%	46%	52%	11%	64%
	CaliforniaPlus	46%	54%	47%	88%	36%
	Rest of US	0%	0%	1%	0%	0%
South America	Northeast US	43%	40%	39%	37%	26%
	Southeast US	52%	56%	48%	37%	60%
	TexasPlus	3%	1%	11%	19%	10%
	CaliforniaPlus	2%	2%	1%	4%	2%
	Rest of US	0%	1%	0%	3%	3%
SE Asia	Northeast US	77%	67%	62%	87%	71%
	Southeast US	1%	4%	3%	0%	0%
	TexasPlus	0%	1%	0%	0%	0%
	CaliforniaPlus	1%	1%	0%	10%	0%
	Rest of US	21%	27%	35%	3%	29%
SW Asia	Northeast US	45%	81%	76%	72%	88%
	Southeast US	30%	0%	7%	8%	0%
	TexasPlus	0%	0%	0%	0%	0%
	CaliforniaPlus	0%	4%	0%	0%	12%
	Rest of US	25%	15%	17%	19%	0%

Heroin Import Seizure Rates

One of the primary purposes of this study is to enable an assessment of U.S. law enforcement's effectiveness in stemming the supply of heroin to U.S. consumers and to identify areas where resource enhancements would further national objectives. Equipped with estimates of the amount of heroin entering the U.S. at various importation regions and import seizures for those regions, it is a simple calculation to derive seizure rates for each region. Table 2 provides seizure rates for each import region from 1996 to 2000. To describe the table briefly, for each U.S. import region, the rates reflect the amount of heroin seized at import in that region divided by the total estimated amount of heroin flowing into that region. The *National Total* row is not an average, but rather the consolidated seizure rate for the nation (i.e., the sum of all heroin import seizures divided by the total estimated flow).

Table 2 - Regional Seizure Rates of Heroin Entering the U.S. (CY 1996-2000)

Import Region	1996	1997	1998	1999	2000
Northeast US	5%	8%	7%	5%	10%
Southeast US	6%	8%	6%	5%	6%
TexasPlus	2%	3%	3%	4%	4%
CaliforniaPlus	2%	3%	2%	1%	4%
Rest of US	6%	8%	10%	6%	11%
National Total	**4%**	**7%**	**5%**	**4%**	**6%**

The implications of this table are obvious. What is perhaps most notable in this table is the low national seizure rates – ranging from 4 percent to 6 percent. Because the majority of heroin is being shipped into the U.S. through the Southeast U.S. and Northeast U.S., performance in these regions has a substantial impact on national effectiveness.

Conclusions

While some of the more detailed results of this model may be dependent upon certain assumptions, on a macro level, several assertions can be made with reasonable confidence:

- South American heroin dominates the U.S. heroin market – both from a supply and consumption perspective – with the bulk of this heroin being shipped through and consumed in the Eastern U.S.
- Mexico is the second largest supplier of heroin into the U.S. with the bulk of it being shipped through and consumed in the Western U.S.
- The flow of South American heroin through the TexasPlus region is increasing.
- U.S. law enforcement agencies are seizing, at best, 10 percent of the heroin moving into and through the U.S., with the majority of seizures occurring at import.

Overview of Approach

Figure 3 provides an overview of the heroin flow model. The method for arriving at estimates for each stage is thoroughly discussed in the following sections and appendices; we provide an overview of the approach here.

The model begins with estimates of U.S. heroin consumption as an approximation of heroin availability on U.S. streets. These consumption estimates come from the most recent version of an annual report that Abt Associates has prepared for the Office of National Drug Control Policy for nearly a decade.[3] Consumption figures are partitioned among four source areas: South America, Mexico, Southeast Asia and Southwest Asia, based on an analysis of data from the Drug Enforcement Administration's Domestic Monitor Program (DMP). The DMP is a retail heroin purchase program designed to identify trends in the price, purity and geographic origin of heroin being sold on U.S. streets. DEA Agents in 22 field offices around the country make ten $100 heroin purchases each quarter.[4] Purchases are sent to DEA's Special Testing Research Lab (STRL) for purity and signature analysis to determine the geographic origin of the heroin.

Street level availability estimates are then augmented by heroin seizures made within the U.S. and upon entry into the U.S. The Federal-Wide Drug Seizure System (FDSS) is used as the data source for heroin seizures. The source area distribution of those seizures is then estimated using data from the Heroin Signature Program (HSP). Like the DMP, the HSP is designed to obtain information on the purity and geographic origin of heroin in the U.S. Under the HSP, DEA field laboratories forward samples of all import seizures[5] and a selection of samples from other seizures and non-DMP purchases to the STRL for signature analysis. The source area distribution figures obtained from HSP data are applied to the FDSS seizure amounts to arrive at estimates of the amount of heroin seized from each source area within the U.S. and at U.S. ports of entry. These figures are then added to the source area-distributed consumption figures. Assuming that traffickers do not warehouse large amounts of heroin in the U.S., the resulting figures should approximate the amount of heroin from each source area that is available for entry into the U.S.

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[3] Rhodes, W., Layne, M., Bruen A., Johnston, P., and Becchetti, L., *What America's Users Spend on Illegal Drugs 1988 – 2000*. Report prepared for the Office of National Drug Control Policy. Abt Associates Inc., December 2001.

[4] The number of purchases, dollar value of purchases and cities involved can vary somewhat, but not substantially.

[5] It is important to note that not all import seizures are forwarded to DEA field laboratories.

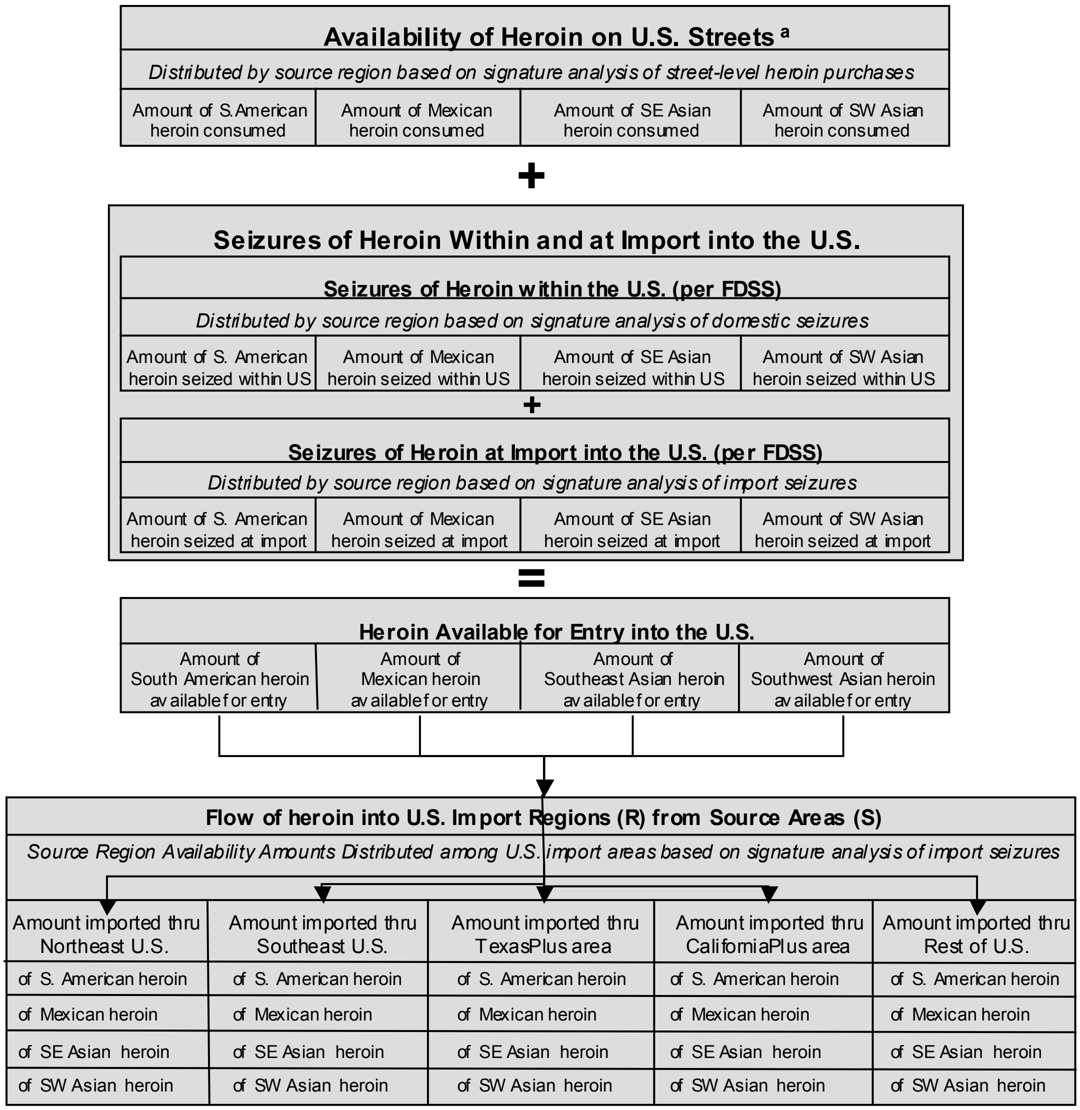
We then construct estimates to approximate the flow of heroin available from the different source areas into the U.S. through various U.S. import regions. To do this, we determine how seizures of heroin from each source area are distributed among the various U.S. import regions (e.g., 64% of Mexican heroin is seized in the TexasPlus region and 36% in CaliforniaPlus). These proportions are applied to the amount of heroin available for entry from source area, A, to estimate the amount of heroin flowing from source area A into import region R. Finally, we calculate seizure rates for each U.S. import region by dividing the amount of heroin seized in each region by the estimated amount of heroin flowing into that region.

It is important to note that this approach assumes that *seizures* of heroin are representative of the *actual flow* of heroin. In other words, if 64 percent of Mexican heroin is seized in the TexasPlus area, then this approach assumes that 64 percent of the heroin available from Mexico is entering the U.S. though the TexasPlus area. What this implies is that the probability of detecting and seizing heroin is the same regardless of the import region. We understand that this is a sweeping – and likely inaccurate – assumption since the probabilities of detecting and seizing heroin will undoubtedly vary among various areas of the country. In the absence of insight into how probabilities of detection might vary, we are left to assume the representativeness of seizures. The specific ramifications of this assumption, in terms of interpreting the results of the model, are discussed in the conclusions section of this report.

One method of checking for possible inconsistencies is to compare our consumption-based estimates of the amount of heroin available for entry into the U.S. with the potential production estimates generated by the Counter Narcotics Center (CNC). Although the CNC estimates have their own set of limitations, a comparison is nevertheless useful. According to reports by the Community Epidemiological Working Group (CEWG) and the U.N. World Drug Report, heroin consumption is minimal within South America and Mexico. Consequently, most South American and Mexican heroin production is probably destined for the U.S. market. Therefore, the consumption-based estimates generated in this report of the amount of heroin available from South America and Mexico for shipment into the U.S. should roughly equal CNC's South American and Mexican production estimates. To the contrary, only a very small proportion of Asian heroin is consumed in the United States. Absent estimates of non-U.S. consumption of Asian heroin, there is no practical way to equate our estimates of the availability of Asian heroin to CNC's Asian heroin production figures.

Tables detailing the calculations for this model are provided in Appendix A. Our approach and observations are discussed in the following sections.

Figure 3 - Overview of the Heroin Flow Model



Seizure Rates for each U.S. Import Region, R = $\frac{\text{Amount Seized in Region, R}}{\text{Amount of Flow into Region, R}}$

[a] Based on heroin consumption estimates presented in the report *What America's Users Spend on Illegal Drugs 1988 – 2000,* prepared for the Office of National Drug Control Policy. Rhodes, W., Layne, M., Bruen, A., Johnston, P., and Becchetti, L. Abt Associates Inc., December 2001.

Availability of Heroin on U.S. Streets

The model begins with estimates of the amount of heroin consumed in the U.S. as representation of the amount of heroin available on U.S. streets. Abt Associates Inc. has produced these estimates for nearly a decade. While early estimates were crude, the methodology has improved over time as new data have become available. Figure 4 summarizes the most recent estimates. An explanation of the methods used to derive these estimates is provided in the report *What America's Users Spend on Illegal Drugs 1988-2000* (Rhodes et al, 2001).

We then determine how heroin consumed in the U.S. is distributed among the various heroin source areas: South America, Mexico, Southeast Asia and Southwest Asia.[6] For this we used DMP records dating back to Calendar Year (CY) 1993[7]. While the DMP provides valuable information about the price, purity and geographic origin of heroin being sold in U.S. cities, it does have limitations. If not accounted for, these limitations can result in misleading – if not inaccurate – results. Appendix B discusses these limitations and our methods for dealing with them in detail. Here we summarize some of the more significant limitations: lack of representativeness and missing signatures.

Neither the sites in which DMP purchases are made, nor the purchases within those sites are selected based on probability sampling. As a consequence, using simple tabulations to construct national estimates can result in over representing cities where heroin use is relatively rare and under representing cities with a large heroin use problem. To correct for this, we used the proportion of drug-related emergency room visits (as reported through the Drug Abuse Warning Network (DAWN)) as a surrogate indicator of the relative level of drug use in each city in our model.[8] City-level data obtained from the DMP were weighted by these DAWN weights for developing national distributions. To illustrate the rationale behind this approach, Table 3 compares the distribution of DAWN data with DMP data. Here, the lack of representation of the DMP data becomes apparent. For example, DMP over-represents heroin purchases in Denver (that is, 5.4% of the DMP records are

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[6] Appendix B provides a detailed, technical discussion of our approach for estimating the source distribution of heroin consumed in the U.S. We provide a general summary of our approach here in the body of the report.

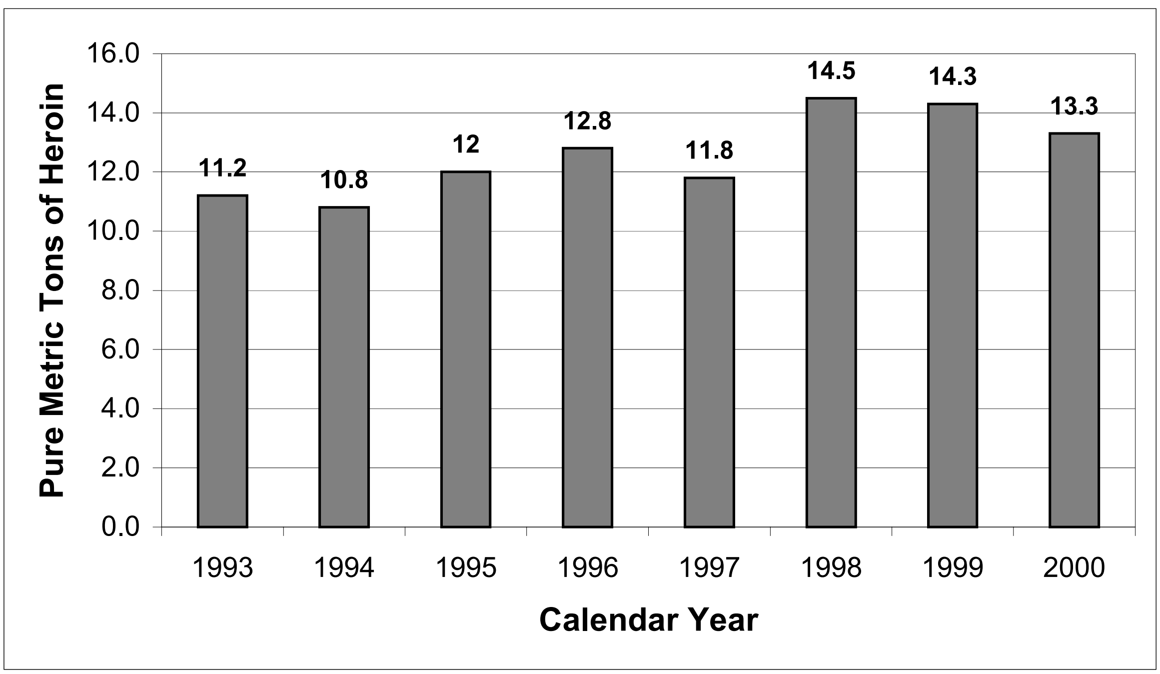
[7] Due to data limitations, calculations throughout the rest of the report date back only to 1996. However, all data (i.e., DMP, DAWN and consumption estimates) that are required to conduct the consumption analysis were available back to 1993. Since the additional years of data improved the robustness of the consumption modeling, they were included.

[8] This is not to imply that emergency room visits are perfectly proportional to heroin use. We use them as a rough adjustment in lieu of any better alternative.

from Denver, whereas only 0.7% of drug-related emergency visits occur in Denver) and under-represents those in New York (9.3% versus 15%).

While this adjustment accounts for the non-randomness of the DMP samples across U.S. cities, it does not account for potential bias in sampling procedures within a city. In other words, it does not address whether the likelihood of acquiring South American heroin in a DMP purchase is greater than the likelihood of acquiring, say, Southwest Asian heroin. Because DMP purchases are made by DEA agents or by confidential informants, it seems possible there could be variances in this likelihood; particularly if DEA has greater success in conducting undercover buys with – or recruiting confidential informants from – South American heroin trafficking organizations. The information required to evaluate this was not readily available, so for purposes of this analysis, we assumed there was no difference in the likelihood of acquiring heroin from the various source areas.

Figure 4 - Heroin Consumption in the U.S. - CY 1993 - 2000 (pure metric tons)



Note: The CY 2000 estimate is a projection.

Source: Rhodes, W., Layne, M., Bruen A.M., Johnston, P., and Becchetti, L., *What America's Users Spend on Illegal Drugs 1988 – 2000, Dec 2001*. Report prepared for the Office of National Drug Control Policy. Abt Associates Inc., December 2001.

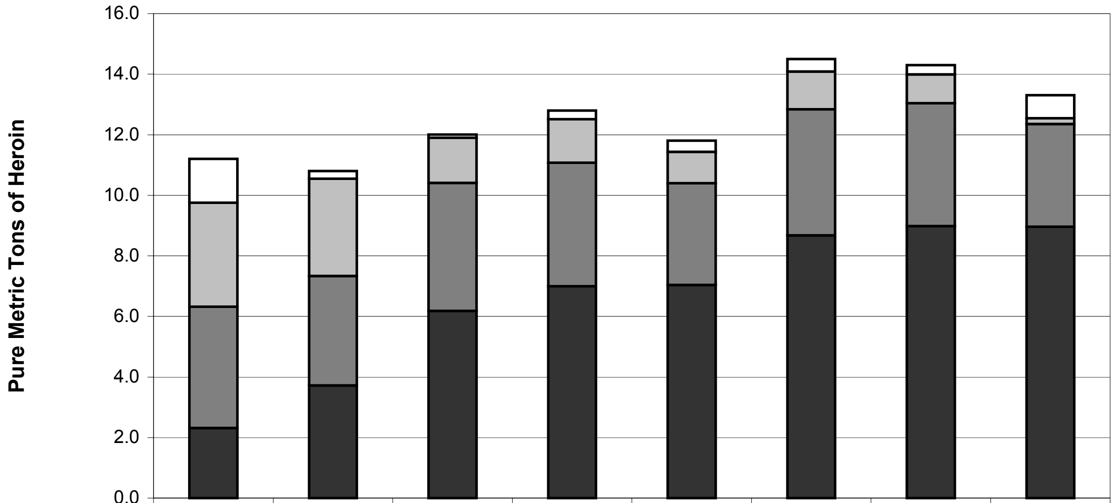
Table 3 -DAWN weights versus DMP weights (averaged over CY 1993-CY2000)

City	DAWN Weight	DMP Weight
Atlanta	0.6	3.9
Baltimore	10.4	4.1
Boston	4.0	3.5
Chicago	10.6	4.3
Dallas	0.6	3.1
Denver	0.7	5.4
Detroit	4.0	4.1
Houston	0.7	4.4
Los Angeles	4.4	4.4
Miami	0.8	3.3
New Orleans	0.6	2.5
New York	15.0	9.3
Newark	7.2	5.5
Philadelphia	5.4	6.2
Phoenix	1.0	5.7
San Diego	1.4	6.1
San Francisco	4.7	3.8
Seattle	3.4	3.8
St. Louis	0.8	4.8
Washington, DC	2.5	4.7
Rest of US	21.1	7.5

We also had to decide how to handle DMP records for which no signature was assigned. Although all DMP purchases are sent to DEA's Special Testing Research Lab (STRL) for signature analysis, for various reasons, signatures were not available for about one-third of the samples[9]. In the absence of information explaining how the ability to assign a signature might vary by the source area of heroin, we imputed missing signature values based on the distribution of known signature values. In other words, for each city and each year, we assume that the source distribution of records whose source is unknown is the same as the source distribution for records whose source is known. Figure 5 provides annual estimates of the amount of heroin consumed in the U.S., distributed by source area.

[9] Of the 6,082 retail DMP purchases between 1993 and 2000, 4,165 had a signature assigned. Of the remaining 1,917 samples, 663 were of an insufficient size and/or purity to assay, 739 could be assayed, but the resulting signature could not be matched to a known signature, and 515 had no entry in the signature field.

Figure 5 -U.S. Consumption of Heroin by Source Area (CY 1993 through CY 2000)



	1993	1994	1995	1996	1997	1998	1999	2000
SW Asia	1.4	0.2	0.1	0.3	0.4	0.4	0.3	0.8
SE Asia	3.4	3.2	1.5	1.4	1.0	1.2	0.9	0.2
Mexico	4.0	3.6	4.2	4.1	3.4	4.2	4.1	3.4
S. America	2.3	3.7	6.2	7.0	7.0	8.7	9.0	9.0

Increasingly, South American heroin is dominating the U.S. heroin market, accounting for more than 67% of the heroin consumed in CY 2000. Mexican heroin made up the second largest share, supplying one-quarter of the U.S.'s heroin consumption. Southeast and Southwest Asian heroin accounted for the remaining supply, with 1.5% and 5.7% of the market share, respectively.

Since 1993, there has been a marked trend for the nation as a whole to favor South American heroin in lieu of Southeast Asian heroin. As illustrated by Figure 6, this substitution has largely been driven by eastern U.S. cities, however, all groups have played a role. Western U.S. cities' consumption of Southeast Asian heroin evaporated after 1994, while the rest of the U.S. steadily increased its consumption of South American heroin over 1993-2000.

Additionally, there has been a mild decline in the proportion of Mexican heroin consumed over the years. This is partly due to a considerable reduction in the consumption of Mexican heroin in cities in the "rest of the U.S." and a slight reduction for eastern U.S. cities. The relative decline in heroin consumption overall in western U.S. cities since 1993 (from 20% of national consumption to 16%) at the expense of the increasing share of consumption with eastern U.S. cities (from 59% to 63%) also contributed to this decline. Not surprisingly, almost all heroin consumed in the western U.S. comes from Mexico. The vast majority of heroin consumed in the eastern U.S. comes from South America. The most striking trend in the eastern U.S. has been the substitution of South American heroin for Southeast Asian heroin. Since 1993, the contribution from Southeast Asia has declined from between 30% and 90% to less than 10%. Following a sharp decline in 1994, the proportion of heroin coming from Southwest Asia appears to be increasing.

Figure 6 - Proportion of Retail Heroin Consumed in the U.S. by Source Area: (a) Mexico, (b) South America, (c) Southwest Asia, (d) Southeast Asia

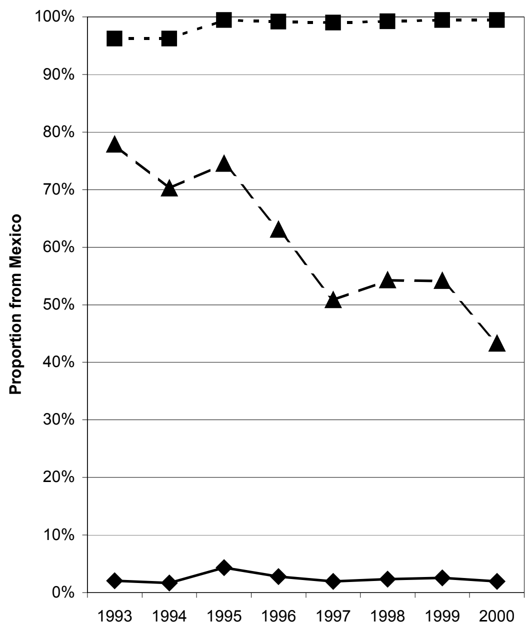


Figure 6a: Mexico

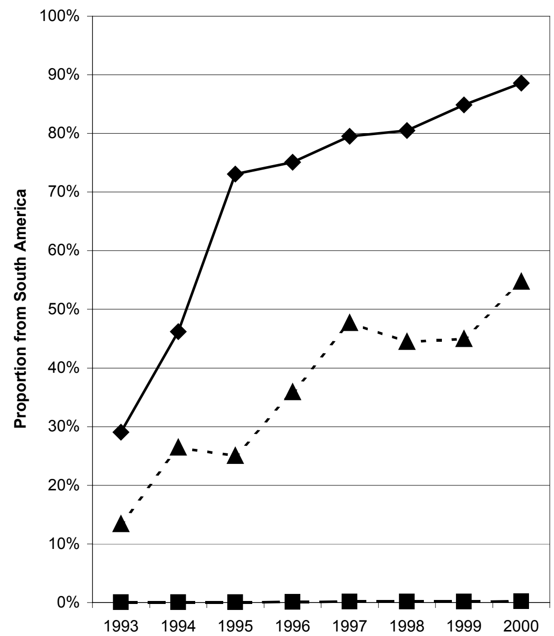


Figure 6b: South America

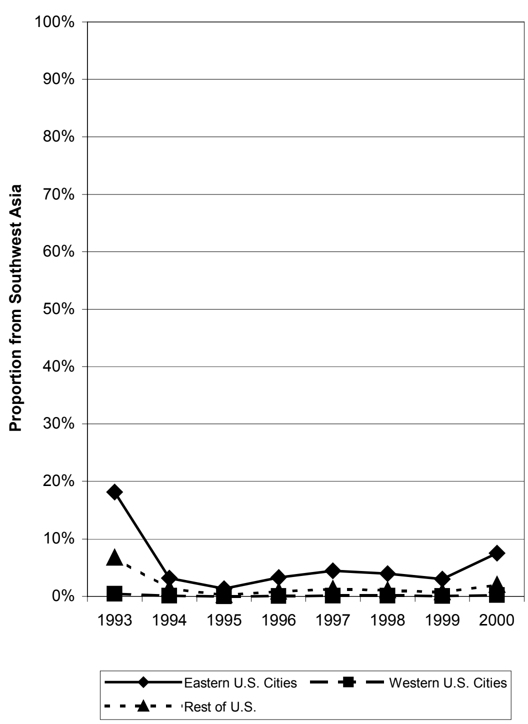


Figure 6c: Southwest Asia

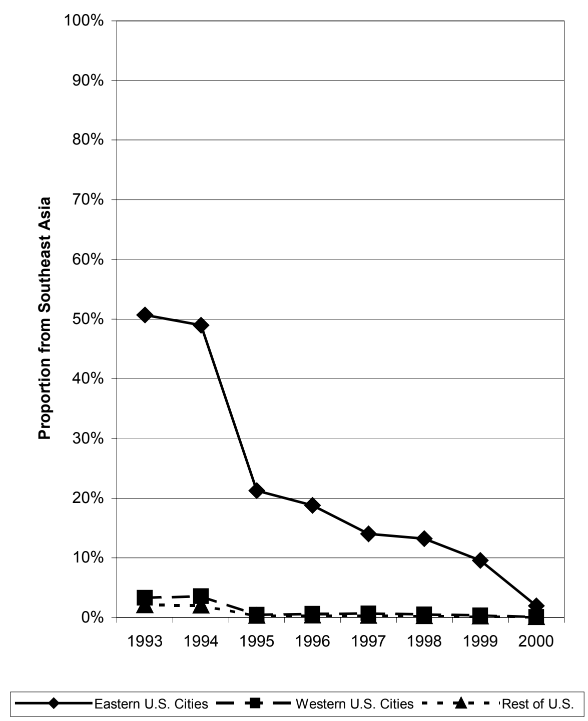
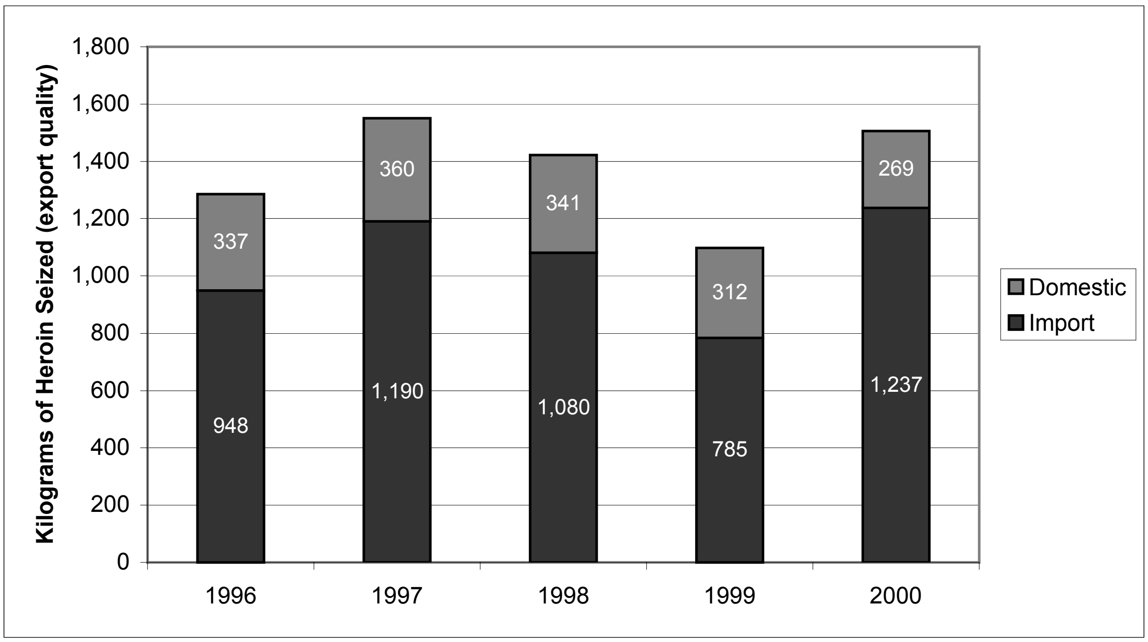


Figure 6d: Southeast Asia

Seizures of Heroin Within and at Import into the U.S.

The next step in our model is to estimate the source area distribution of seizures. For this, we used the Federal-wide Drug Seizure System (FDSS) as the data source for heroin seizures within the U.S. ("domestic" seizures) and upon entry into the U.S. ("import" seizures). Figure 7 below shows annual totals for domestic and import heroin seizures since 1996.[10]

Figure 7 -Heroin Seizures at Import and Within the U.S. (1996-2000)



Sources: Analysis of Federal-wide Drug Seizure System and Heroin Signature Program data.

To distribute these seizures by source area, we turned to data from the HSP. We found, however, that when aggregated according to the U.S. regions we established for this report, HSP data were not representative of the FDSS data. To illustrate this problem, Table 4 compares the U.S. regional distribution of import seizures in the HSP with those in the FDSS. The Northeast U.S., for example is over represented in the HSP whereas the TexasPlus area is severely under represented. This lack of representativeness of the HSP data prevented us from using a simple tabulation of the national source area distribution of HSP seizure records for determining the national source area distribution of seizures.

[10] We did not have FDSS log data for seizures that occurred prior to 1997. Since FDSS log data provide details regarding how the seizure was acquired, we estimated the domestic/import distribution of seizures in 1996 by using the average of domestic/import distribution percentages from 1997 through 2000.

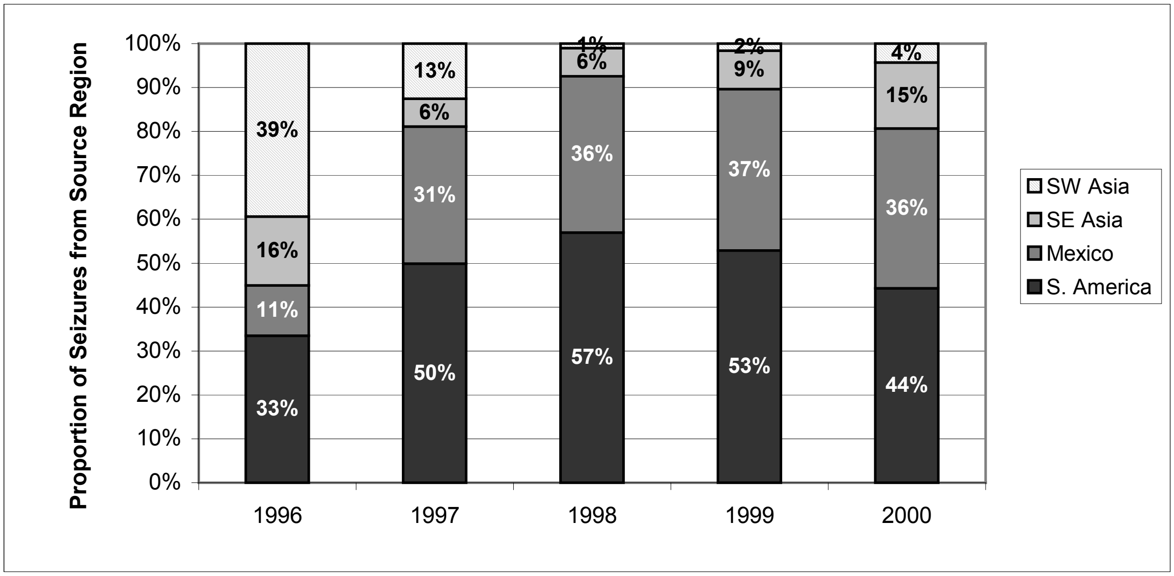
Table 4 - Geographic distribution of import seizures in the HSP vs. FDSS - CY 2000

U.S. Region	Distribution of seizures in HSP	Distribution of seizures in FDSS
Northeast US	43.1%	35.7%
Southeast US	41.1%	32.0%
TexasPlus	3.0%	17.9%
CaliforniaPlus	11.4%	10.2%
Rest of US	1.4%	4.2%
	100.0%	100.0%

To correct for this misrepresentation in developing national distribution estimates, we weighted the source area signature proportions for each U.S. region according to each regions' share of national seizures. Appendix C walks the reader through an explanation of this process using import seizures in CY 2000 as an example.

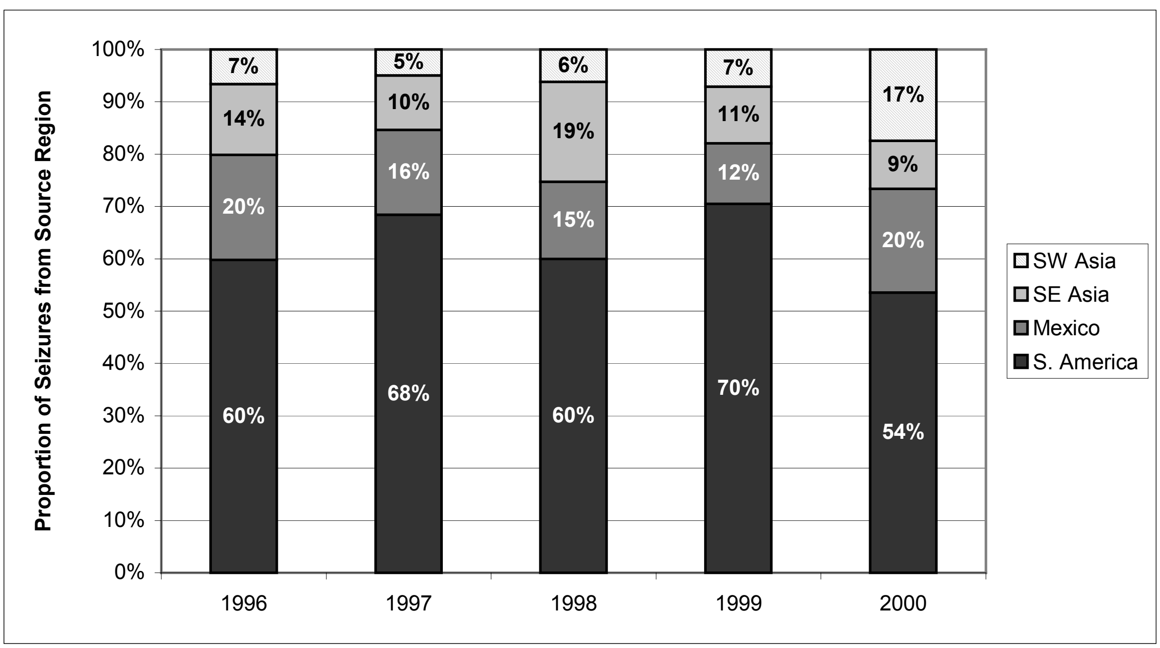
The following charts show the resulting national estimates of how U.S. domestic and import seizures have been distributed by source area since 1996. Not surprisingly, South American heroin makes up the largest – and Mexican heroin, the second largest – share of seizures made both within the U.S. and at U.S. borders. What is interesting, however, is the difference in proportions between domestic and import seizures. A much larger share of import heroin seizures are from South America. Contrarily, the proportion of Mexican heroin seized at U.S. borders is much smaller than that seized within the U.S. Comparing these proportions to consumption figures would suggest that border interdiction agencies have greater success at identifying and seizing heroin from South America than from Mexico. Additional implications about these figures are discussed later in the context of seizure rates.

Figure 8 - National Source Distribution of Domestic Heroin Seizures, CY 1996-2000



Per analysis of HSP domestic seizure records; export quality amounts used for calculations.

Figure 9 - National Source Distribution of Import Heroin Seizures (1996-2000)



Per analysis of HSP import seizure records; export quality amounts used for calculations.

We then apply these distribution proportions from the HSP data to domestic and import seizure amounts from the FDSS. This yields the amount of heroin seized from each source area at import and within the U.S. Table 5 provides these figures, converted into pure kilograms.[11]

Table 5 - Domestic and Import Heroin Seizures by Source Area (in pure kilograms)

		Calendar Year				
		1996	1997	1998	1999	2000
Domestic seizures (pure kg)	Mexico	17.00	49.44	53.53	50.50	43.11
Domestic seizures (pure kg)	SOAM	90.16	143.86	155.56	132.12	95.30
Domestic seizures (pure kg)	SE Asia	39.65	17.19	16.48	20.54	30.47
Domestic seizures (pure kg)	SW Asia	99.40	33.94	2.53	3.81	8.62
Domestic seizures (pure kg)		**246.21**	**244.43**	**228.10**	**206.97**	**177.49**
Import seizures (pure kg)	Mexico	83.76	84.86	70.04	40.07	108.02
Import seizures (pure kg)	SOAM	453.64	651.49	518.16	442.37	529.63
Import seizures (pure kg)	SE Asia	96.19	93.01	155.16	63.46	85.33
Import seizures (pure kg)	SW Asia	46.97	44.34	49.83	41.92	161.72
Import seizures (pure kg)		**680.57**	**873.71**	**793.19**	**587.82**	**884.71**
Total seizures (pure kg)		***926.78***	***1,118.14***	***1,021.29***	***794.79***	***1,062.20***

[11] According to an analysis of HSP import seizure data, South American heroin has been about 80 percent pure since 1996, while Mexican heroin has been about 44 percent pure. Heroin from Southeast and Southwest Asia has typically been 75 percent pure. (*Estimation of Heroin Availability, 1995-1998*; Rhodes et al, 2000.)

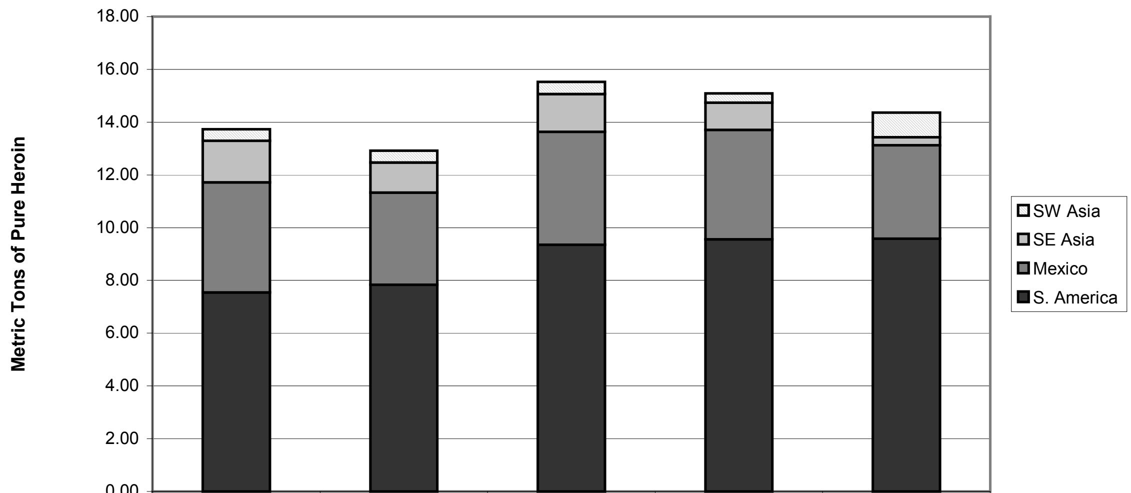
Estimates of the Amount of Heroin Available for Entry into the United States

By adding domestic and import seizures to consumption estimates, we arrive at what should be reasonable approximations of the amount of heroin that is being presented for entry into the U.S. (in total and from each source area). Table 6 summarizes these calculations. Annual trends in the amount and source area distribution of heroin available for entry into the U.S. are displayed in the chart that follows. Clearly, the consumption figures dominate the resulting availability estimates. Accordingly, the trends for availability are virtually identical to those for consumption, with South American heroin playing an increasing role, largely at the expense of Southeast Asian heroin.

Table 6 - Summary of Calculations for Estimating Heroin Availability (in pure kilograms)

		Calendar Year				
		1996	1997	1998	1999	2000
Consumption	Mexico	4,075.5	3,357.4	4,169.2	4,051.5	3,391.3
	S. America	6,999.2	7,040.7	8,672.5	8,988.0	8,958.2
	SE Asia	1,438.8	1,034.2	1,249.4	947.7	191.3
	SW Asia	286.5	367.7	408.8	312.9	759.2
	Total Consumption	**12,800.0**	**11,800.0**	**14,500.0**	**14,300.0**	**13,300.0**
Domestic seizures	Mexico	17.0	49.4	53.5	50.5	43.1
	S. America	90.2	143.9	155.6	132.1	95.3
	SE Asia	39.6	17.2	16.5	20.5	30.5
	SW Asia	99.4	33.9	2.5	3.8	8.6
	Total Domestic seizures	**246.2**	**244.4**	**228.1**	**207.0**	**177.5**
Import seizures	Mexico	83.8	84.9	70.0	40.1	108.0
	S. America	453.6	651.5	518.2	442.4	529.6
	SE Asia	96.2	93.0	155.2	63.5	85.3
	SW Asia	47.0	44.3	49.8	41.9	161.7
	Total Import seizures	**680.6**	**873.7**	**793.2**	**587.8**	**884.7**
Heroin available for entry into U.S.	Mexico	4,176.3	3,491.7	4,292.8	4,142.0	3,542.5
	S. America	7,543.0	7,836.1	9,346.3	9,562.5	9,583.1
	SE Asia	1,574.6	1,144.4	1,421.1	1,031.6	307.1
	SW Asia	432.9	446.0	461.1	358.7	929.5
	Total amount available for entry	**13,726.8**	**12,918.1**	**15,521.3**	**15,094.8**	**14,362.2**

Figure 10 - Estimates of Heroin Available for Entry Into the U.S., CY 1996-2000



	1996	1997	1998	1999	2000
SW Asia	0.43	0.45	0.46	0.36	0.93
SE Asia	1.57	1.14	1.42	1.03	0.31
Mexico	4.18	3.49	4.29	4.14	3.54
S. America	7.54	7.84	9.35	9.56	9.58

Comparison of Consumption-based Availability Estimates with CNC Potential Production Estimates

The Crime and Narcotics Center (CNC) provides annual estimates of heroin production potential for the various heroin-producing countries. Assuming the majority of heroin produced in Mexico and South America is destined for U.S. markets, after accounting for seizures and other losses, the consumption-based estimates generated in this report should agree with the CNC estimates - at least roughly – for South America and Mexico. If not, something is wrong with the consumption-based estimates, with CNC's production estimates, or with both. CNC also estimates potential production for Southeast and Southwest Asian heroin. While we know that only a small portion of these areas' heroin production is destined for the U.S., we do not know how small. Absent estimates of non-U.S. consumption of Asian heroin, there is no apparent way to compare our consumption-based availability estimates with CNC's potential production estimates for Asian heroin.

Table 7 shows how our consumption-based estimates of heroin availability from Mexico and South America compare with CNC's reports of production potential. With the exception of CY 1999 and 2000, the consumption-based estimates for Mexico are less than the CNC potential production figures. For South American heroin, the consumption-based estimates are consistently higher than the CNC estimates. Further, the 6.5 metric ton potential production estimate for CY 2000 published by CNC could very well underestimate production for that year. Heroin production potential in South America has steadily increased over the years, so it might be more appropriate to simply carry over the 8 metric ton estimate from 1999 to 2000, rather than using an average of the past five years. Explanation for these differences would require further understanding of the uncertainties in each estimate, which are currently not available. As research such as this project continues, improvements in estimation data and processes will provide more accurate drug availability estimates.

It is also possible that our consumption-based estimates overestimate the contribution of South American heroin and underestimate the contribution of Asian heroin. As we discussed earlier, the source area distributions are obtained from purchases and seizures of heroin by U.S. law enforcement agencies. Absent the information necessary to prove otherwise, the model assumes that the probabilities of obtaining heroin (whether via a purchase or seizure) are the same for all source areas. If, however, it is more difficult for law enforcement agencies to purchase or seize Asian heroin than South American heroin, then our model would be over estimating the availability of South American heroin in the U.S. and underestimating the availability of Asian heroin

Table 7 - Comparison of Consumption Based Heroin Availability Estimates with CNC Potential Production Estimates, 1996-2000 (metric tons)

		1996	1997	1998	1999	2000
Mexico	Consumption-based availability	4.2	3.5	4.3	4.1	3.5
	CNC potential production	5.0	4.0	6.0	4.0	2.5
South America	Consumption-based availability	7.5	7.8	9.3	9.6	9.6
	CNC potential production	6.0	6.0	6.0	8.0	6.5[a]

[a] Colombia production data for 2000 are not available. This is an average of production estimates from 1995-1999.

The Movement of Heroin from Source Areas into the United States

Now that we have estimates of the amount of heroin that is available from each source area for entry into the U.S., our next task is to approximate where this heroin is entering the U.S. For this, we return to our analysis of HSP and FDSS data. If we assume that seizures are proportional to the flow, then the U.S. import region distribution of seizures of heroin from each source area would also represent the proportion of each source area's supply that is shipped through these regions. To illustrate, Table 8 shows how import seizures in CY 2000 were distributed by source area and U.S. import region. Of the total amount of Mexican heroin seized at import into the U.S. in CY 2000, 36 percent was seized in the CaliforniaPlus region and 64 percent in the TexasPlus region. If seizures are representative of the flow, then this means that 36 percent of the Mexican heroin available for shipment into the U.S. is entering through the CaliforniaPlus region and 64 percent through the TexasPlus region.

Table 8 - Distribution of Heroin Seizures by Source Area and U.S. Import Region - CY 2000

	Source Area			
U.S. Import Region	South America	Mexico	SE Asia	SW Asia
CaliforniaPlus	2.02%	35.53%	0.00%	12.08%
Northeast	25.78%	0.00%	71.39%	87.67%
Other	2.88%	0.00%	28.61%	0.00%
Southeast	59.72%	0.00%	0.00%	0.25%
TexasPlus	9.60%	64.47%	0.00%	0.00%
TOTAL	100.00%	100.00%	100.00%	100.00%

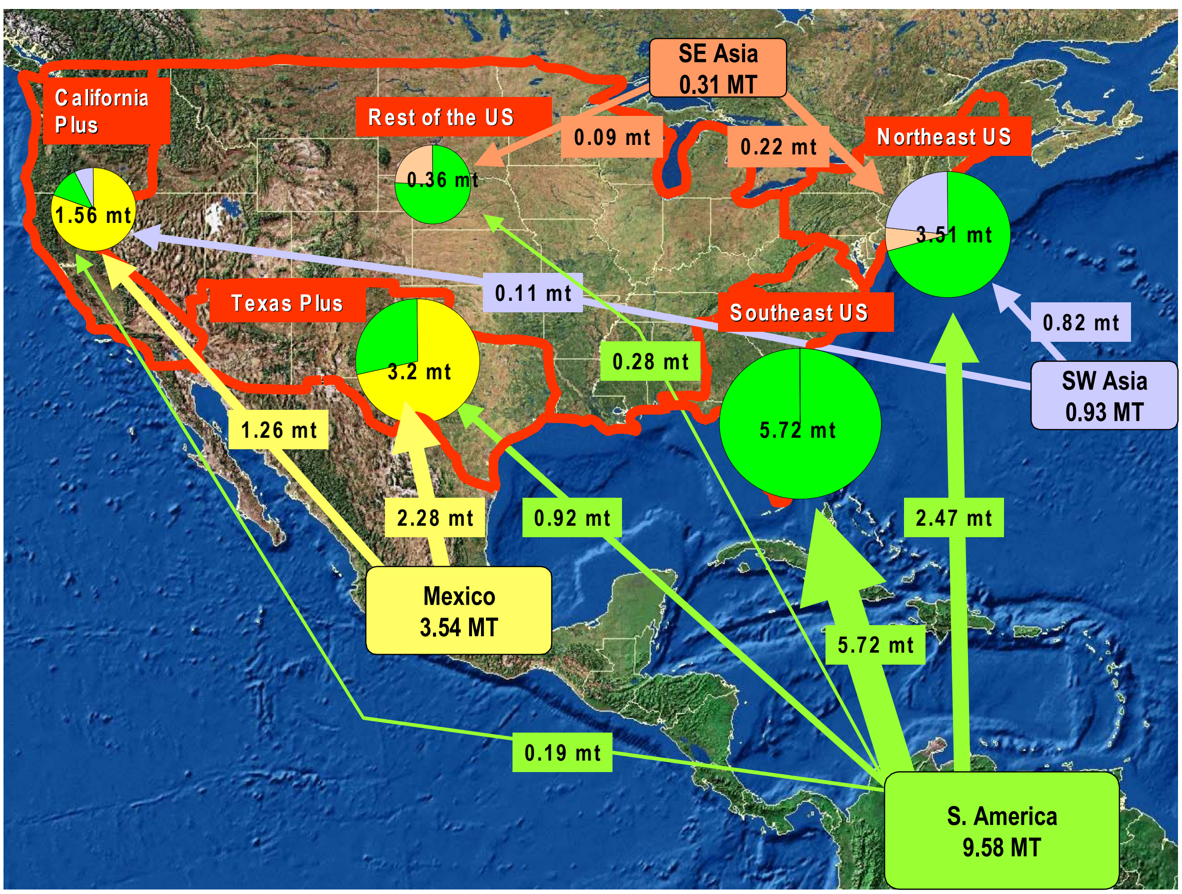
Applying these regional seizure distributions to availability estimates, we arrive at the amount of heroin flowing from each source area into the U.S. through the various import regions. The map in Figure 11 below illustrates this concept using CY 2000 estimates.

The Southeast U.S. is the preferred import region for South American heroin. This is not surprising when one considers the proximity of this region to South America and the availability of direct commercial airline flights from Colombia to Miami. Since South American heroin makes up two-thirds of our nation's heroin supply, this also gives the Southeast U.S. the distinction of being the primary importation region for *all* heroin entering the U.S. In fact, 40 percent of the heroin entering the U.S. (or 5.72 pure metric tons) does so through the Southeast U.S.

About one quarter of the heroin entering the U.S. comes through the Northeast U.S. The majority of Asian heroin enters the U.S. through the Northeast region. Although Asian heroin comprises less than 10 percent of the total flow, it accounts for over a quarter of the flow through the Northeast.

Slightly less than one quarter (22%) of the heroin flow enters the U.S. through the TexasPlus region. The majority of this heroin is Mexican, but more than a quarter is from South America. Only eleven percent (1.56 metric tons) of heroin entering the U.S. comes through the CaliforniaPlus region. The majority of the flow into this region is Mexican heroin; relatively small amounts of South American and Southwest Asian heroin enters the U.S. through the CaliforniaPlus region. The Rest of the U.S. accounts for the remaining 3 percent (0.36 metric tons) of the heroin flowing across our borders; comprised largely of South American heroin with small amounts of Southeast Asian heroin.

Figure 11 - The Flow of Heroin From Source Areas Into the U.S. - CY 2000



The following table shows annual trends in the distribution of heroin into the U.S. through the various import areas from 1996 to 2000. Mexican heroin has consistently moved into the U.S. through the CaliforniaPlus and TexasPlus regions. The Northeast U.S. and Southeast U.S. have been the primary import areas for South American heroin, with a trend towards more imports flowing through the Southeast. The TexasPlus region has also increased in importance as an importation region for South American heroin. The Northeast U.S. has been the preferred importation region for both forms of Asian heroin, with the Rest of the U.S. being the second preferred region of entry.

Table 9 -Distribution of Flow from Source Areas into the U.S.

Source Area	Import Region	1996	1997	1998	1999	2000
Mexico	Northeast US	0%	0%	0%	0%	0%
	Southeast US	0%	0%	0%	1%	0%
	TexasPlus	54%	46%	52%	11%	64%
	CaliforniaPlus	46%	54%	47%	88%	36%
	Rest of US	0%	0%	1%	0%	0%
South America	Northeast US	43%	40%	39%	37%	26%
	Southeast US	52%	56%	48%	37%	60%
	TexasPlus	3%	1%	11%	19%	10%
	CaliforniaPlus	2%	2%	1%	4%	2%
	Rest of US	0%	1%	0%	3%	3%
SE Asia	Northeast US	77%	67%	62%	87%	71%
	Southeast US	1%	4%	3%	0%	0%
	TexasPlus	0%	1%	0%	0%	0%
	CaliforniaPlus	1%	1%	0%	10%	0%
	Rest of US	21%	27%	35%	3%	29%
SW Asia	Northeast US	45%	81%	76%	72%	88%
	Southeast US	30%	0%	7%	8%	0%
	TexasPlus	0%	0%	0%	0%	0%
	CaliforniaPlus	0%	4%	0%	0%	12%
	Rest of US	25%	15%	17%	19%	0%

The tables in Appendix A provide the actual flow amounts for each source area, by import region for 1996 through 2000.

Heroin Import Seizure Rates

One of the primary purposes of this study is to enable an assessment of U.S. law enforcement's effectiveness in stemming the supply of heroin to U.S. consumers and to identify areas where resource enhancements would further national objectives. Equipped with estimates of the amount of heroin entering the U.S. at various importation regions and import seizures for those regions, it is a simple calculation to derive seizure rates for each region. Table 10 provides seizure rates for each import region from 1996 to 2000. The figures behind these calculations are presented in Appendix A. To describe the table briefly, for each U.S. import region, the rates reflect the amount of heroin seized at import in that region divided by the total estimated amount of heroin flowing into that region. The *National Total* row is not an average, but rather the consolidated seizure rate for the nation (i.e., the sum of all heroin import seizures divided by the total estimated flow).

Table 10 - Regional Seizure Rates of Heroin Entering the U.S. (CY 1996 - 2000)

Import Region	1996	1997	1998	1999	2000
Northeast US	5%	8%	7%	5%	10%
Southeast US	6%	8%	6%	5%	6%
TexasPlus	2%	3%	3%	4%	4%
CaliforniaPlus	2%	3%	2%	1%	4%
Rest of US	6%	8%	10%	6%	11%
National Total	**4%**	**7%**	**5%**	**4%**	**6%**

The implications of this table are obvious. What is perhaps most notable in this table is the low national seizure rates – ranging from 4 percent to 6 percent. Because the majority of heroin is being shipped into the U.S. through the Southeast U.S. and Northeast U.S., performance in these regions has a substantial impact on national effectiveness.

Conclusions

The fact that our consumption-based estimates of the amount of heroin available for import into the U.S. from South America and Mexico are not vastly different from CNC's potential production estimates is compelling, but not convincing, evidence that this heroin flow model provides an accurate profile of how much heroin enters the U.S., how it gets here, and where it comes from.

One of the greatest limitations of this model is the assumption that seizures are, to a certain degree, representative of the flow. Since seizures comprise such a small portion of the availability figures, the effect of this assumption in estimating the amount of heroin available from each country for shipment into the U.S. is minimal. Where this assumption has a greater effect is in determining through what regions heroin is being imported into the U.S. Resolving this problem, however, requires an examination into how the probabilities of detecting heroin entering the U.S. vary across the country.

While some of the more detailed results of this model may be dependent upon assumptions, on a macro level, certain assertions can be made with reasonable confidence:

- South American heroin dominates the U.S. heroin market – both from a supply and consumption perspective – with the bulk of this heroin being shipped through and consumed in the Eastern U.S.
- Mexico is the second largest supplier of heroin into the U.S. with the bulk of it being shipped through and consumed in the Western U.S.
- The flow of South American heroin through the TexasPlus region is increasing.
- U.S. law enforcement agencies are seizing, at best, 10 percent of the heroin moving into and through the U.S., with the majority of seizures occurring at impor.

Appendix A – Summary Tables of Calculations

Calculations for Estimating the Amount of Heroin Available for Entry into the U.S.

MEASURE		REFERENCE	1996	1997	1998	1999	2000
Consumption (pure mt)	**TOTAL**	**Abt Retail Sales**	**12.8**	**11.8**	**14.5**	**14.3**	**13.3**
Source distribution at consumption	Mexico	Abt Heroin paper	31.84%	28.45%	28.75%	28.33%	25.50%
	SOAM	Abt Heroin paper	54.68%	59.67%	59.81%	62.85%	67.35%
	SE Asia	Abt Heroin paper	11.24%	8.76%	8.62%	6.63%	1.44%
	SW Asia	Abt Heroin paper	2.24%	3.12%	2.82%	2.19%	5.71%
Consumption (pure mt)	Mexico	Calculation	4.08	3.36	4.17	4.05	3.39
	SOAM	Calculation	7.00	7.04	8.67	8.99	8.96
	SE Asia	Calculation	1.44	1.03	1.25	0.95	0.19
	SW Asia	Calculation	0.29	0.37	0.41	0.31	0.76
Purity	Mexico	Abt Heroin paper	44%	44%	44%	44%	44%
	SOAM	Abt Heroin paper	80%	80%	80%	80%	80%
	SE Asia	Abt Heroin paper	75%	75%	75%	75%	75%
	SW Asia	Abt Heroin paper	75%	75%	75%	75%	75%
Domestic Seizures (mt)	**TOTAL**	**FDSS**	**(0.45)**	**(0.36)**	**(0.34)**	**(0.31)**	**(0.27)**
Source distribution of domestic seizures	Mexico	Abt Heroin paper	11.47%	31.18%	35.63%	36.74%	36.39%
	SOAM	Abt Heroin paper	33.47%	49.90%	56.95%	52.87%	44.25%
	SE Asia	Abt Heroin paper	15.70%	6.36%	6.43%	8.76%	15.09%
	SW Asia	Abt Heroin paper	39.36%	12.56%	0.99%	1.63%	4.27%
Domestic seizures (pure mt)	Mexico	Calculation	(0.02)	(0.05)	(0.05)	(0.05)	(0.04)
	SOAM	Calculation	(0.12)	(0.14)	(0.16)	(0.13)	(0.10)
	SE Asia	Calculation	(0.05)	(0.02)	(0.02)	(0.02)	(0.03)
	SW Asia	Calculation	(0.13)	(0.03)	(0.00)	(0.00)	(0.01)
	SUM		**(0.33)**	**(0.24)**	**(0.23)**	**(0.21)**	**(0.18)**
Heroin available in the U.S. (pure mt)	Mexico	Calculation	4.10	3.41	4.22	4.10	3.43
	SOAM	Calculation	7.12	7.18	8.83	9.12	9.05
	SE Asia	Calculation	1.49	1.05	1.27	0.97	0.22
	SW Asia	Calculation	0.42	0.40	0.41	0.32	0.77
	SUM		**13.13**	**12.04**	**14.73**	**14.51**	**13.48**
Import Seizures (mt)	**TOTAL**	**FDSS**	**(0.84)**	**(1.19)**	**(1.08)**	**(0.78)**	**(1.24)**
Source distribution of import seizures	Mexico	Abt Heroin paper	20.07%	16.20%	14.74%	11.61%	19.85%
	SOAM	Abt Heroin paper	59.80%	68.41%	59.96%	70.48%	53.52%
	SE Asia	Abt Heroin paper	13.53%	10.42%	19.15%	10.79%	9.20%
	SW Asia	Abt Heroin paper	6.60%	4.97%	6.15%	7.12%	17.43%
Import seizures (pure mt)	Mexico	Calculation	(0.07)	(0.08)	(0.07)	(0.04)	(0.11)
	SOAM	Calculation	(0.40)	(0.65)	(0.52)	(0.44)	(0.53)
	SE Asia	Calculation	(0.09)	(0.09)	(0.16)	(0.06)	(0.09)
	SW Asia	Calculation	(0.04)	(0.04)	(0.05)	(0.04)	(0.16)
	SUM		**(0.60)**	**(0.87)**	**(0.79)**	**(0.59)**	**(0.88)**
Heroin available for entry into the U.S. (pure mt)	Mexico	Calculation	4.17	3.49	4.29	4.14	3.54
	SOAM	Calculation	7.52	7.84	9.35	9.56	9.58
	SE Asia	Calculation	1.58	1.14	1.42	1.03	0.31
	SW Asia	Calculation	0.46	0.45	0.46	0.36	0.93
	SUM		**13.73**	**12.92**	**15.52**	**15.09**	**14.36**

Calculations for Approximating the Flow of Heroin into the U.S.

Measure	From Source Area	To U.S. Import Region	1996	1997	1998	1999	2000
Import Seizures by Source and Import Region	Mexico	Northeast US	0.00	0.00	0.00	0.00	0.00
(in export quality kilograms)		Southeast US	0.00	0.00	0.00	0.98	0.00
		TexasPlus	76.31	89.04	82.63	10.14	158.28
		CaliforniaPlus	64.16	103.82	75.39	79.94	87.22
		Rest of US	0.00	0.00	1.16	0.00	0.00
		TOTAL	**140.47**	**192.86**	**159.18**	**91.06**	**245.50**
	S. America	Northeast US	221.92	329.47	251.49	203.83	170.70
		Southeast US	265.85	458.91	313.72	206.50	395.40
		TexasPlus	14.99	4.82	74.46	105.84	63.53
		CaliforniaPlus	12.61	12.71	5.95	19.71	13.34
		Rest of US	0.00	8.47	2.09	17.08	19.07
		TOTAL	**515.37**	**814.37**	**647.71**	**552.96**	**662.04**
	SE Asia	Northeast US	78.98	83.10	127.32	73.55	81.22
		Southeast US	1.10	5.47	6.87	0.00	0.00
		TexasPlus	0.00	1.24	0.00	0.00	0.00
		CaliforniaPlus	1.33	0.77	0.59	8.55	0.00
		Rest of US	21.06	33.44	72.10	2.52	32.55
		TOTAL	**102.47**	**124.02**	**206.88**	**84.61**	**113.77**
	SW Asia	Northeast US	22.90	47.95	50.49	40.45	189.06
		Southeast US	15.46	0.00	4.73	4.65	0.54
		TexasPlus	0.00	0.00	0.00	0.00	0.00
		CaliforniaPlus	0.00	2.29	0.00	0.00	26.04
		Rest of US	13.03	8.89	11.22	10.79	0.00
		TOTAL	**51.39**	**59.12**	**66.44**	**55.90**	**215.63**
Distribution of Flow from Source Areas into U.S.	Mexico	Northeast US	0%	0%	0%	0%	0%
		Southeast US	0%	0%	0%	1%	0%
		TexasPlus	54%	46%	52%	11%	64%
		CaliforniaPlus	46%	54%	47%	88%	36%
		Rest of US	0%	0%	1%	0%	0%
	S. America	Northeast US	43%	40%	39%	37%	26%
		Southeast US	52%	56%	48%	37%	60%
		TexasPlus	3%	1%	11%	19%	10%
		CaliforniaPlus	2%	2%	1%	4%	2%
		Rest of US	0%	1%	0%	3%	3%
	SE Asia	Northeast US	77%	67%	62%	87%	71%
		Southeast US	1%	4%	3%	0%	0%
		TexasPlus	0%	1%	0%	0%	0%
		CaliforniaPlus	1%	1%	0%	10%	0%
		Rest of US	21%	27%	35%	3%	29%
	SW Asia	Northeast US	45%	81%	76%	72%	88%
		Southeast US	30%	0%	7%	8%	0%
		TexasPlus	0%	0%	0%	0%	0%
		CaliforniaPlus	0%	4%	0%	0%	12%
		Rest of US	25%	15%	17%	19%	0%

Measure	From Source Area	To U.S. Import Region	1996	1997	1998	1999	2000
Flow from Source Areas to Import Regions	Mexico	Northeast US	0	0	0	0	0
(in pure kilograms)		Southeast US	0	0	0	45	0
		TexasPlus	2,267	1,612	2,228	461	2,284
		CaliforniaPlus	1,906	1,880	2,033	3,636	1,259
		Rest of US	0	0	31	0	0
	S. America	Northeast US	3,238	3,170	3,629	3,525	2,471
		Southeast US	3,879	4,416	4,527	3,571	5,724
		TexasPlus	219	46	1,074	1,830	920
		CaliforniaPlus	184	122	86	341	193
		Rest of US	0	81	30	295	276
	SE Asia	Northeast US	1,215	767	875	897	219
		Southeast US	17	50	47	0	0
		TexasPlus	0	11	0	0	0
		CaliforniaPlus	20	7	4	104	0
		Rest of US	324	309	495	31	88
	SW Asia	Northeast US	205	362	350	260	815
		Southeast US	138	0	33	30	2
		TexasPlus	0	0	0	0	0
		CaliforniaPlus	0	17	0	0	112
		Rest of US	117	67	78	69	0
Import Seizures by Source and Import Region	Mexico	Northeast US	0	0	0	0	0
(in pure kilograms)		Southeast US	0	0	0	0	0
		TexasPlus	34	39	36	4	70
		CaliforniaPlus	28	46	33	35	38
		Rest of US	0	0	1	0	0
	S. America	Northeast US	178	264	201	163	137
		Southeast US	213	367	251	165	316
		TexasPlus	12	4	60	85	51
		CaliforniaPlus	10	10	5	16	11
		Rest of US	0	7	2	14	15
	SE Asia	Northeast US	59	62	95	55	61
		Southeast US	1	4	5	0	0
		TexasPlus	0	1	0	0	0
		CaliforniaPlus	1	1	0	6	0
		Rest of US	16	25	54	2	24
	SW Asia	Northeast US	17	36	38	30	142
		Southeast US	12	0	4	3	0
		TexasPlus	0	0	0	0	0
		CaliforniaPlus	0	2	0	0	20
		Rest of US	10	7	8	8	0
Heroin import seizure rates		Northeast US	5%	8%	7%	5%	10%
		Southeast US	6%	8%	6%	5%	6%
		TexasPlus	2%	3%	3%	4%	4%
		CaliforniaPlus	2%	3%	2%	1%	4%
		Rest of US	6%	8%	10%	6%	11%

Appendix B – Technical Discussion of Retail Distribution Analysis

Introduction

The analysis reported here is based on the Domestic Monitoring Program (DMP) subset of the System To Retrieve Information from Drug Evidence (STRIDE) heroin database over the eight-year period 1993-2000. Over this period, the DMP database contained 6232 observations, of which 6177 were purchases, and 6082 were retail purchases (at most $200). Of the 6082 retail purchases, 4165 came from a known source (Mexico, South America, South East Asia, or South West Asia), while the source of the remaining 1917 was unknown. The reasons for source being unknown were varied: 663 were of an insufficient magnitude (size and/or purity) to assay, 739 could be assayed but the resulting signature could not be matched to a known signature, and 515 were simply missing. The distributions over time for the "known" and "unknown" subsets are shown in Tables B1 and B2.

Table B1. Distribution of DMP Sample Size: Known Source Areas

Source Area	1993	1994	1995	1996	1997	1998	1999	2000
Mexico	180	182	252	218	224	317	294	249
South America	46	123	190	241	246	316	291	268
SE Asia	102	116	43	53	28	48	25	5
SW Asia	31	8	3	10	11	15	9	21
Total Known	359	429	488	522	509	696	619	543

Table B2. Distribution of DMP Sample Size: Unknown Source Areas

Source Area	1993	1994	1995	1996	1997	1998	1999	2000
Sufficient but Unknown	253	164	61	36	30	58	74	63
Insufficient to Assay	0	58	138	129	102	111	73	52
Missing	42	29	47	66	86	84	96	65
Total Unknown	295	251	246	231	218	253	243	180

Our primary analysis is based on the 4165 retail purchases coming from a known source. This amounts to treating the unknowns as "missing at random", an assumption which may or may not be warranted, and one we revisit at the end of the report. The known sample was distributed over 20 cities, each of which being a Metropolitan Statistical Area (MSA), as well as 33 other locations which were grouped to form the "Rest of U.S." From the viewpoint of the model, the Rest of U.S. is just another "city", and in the interests of brevity we use "21 cities" and "20 cities and the Rest of U.S." interchangeably. The distribution of the sample over cities and years is shown in Table B3.

Supplementary tables B8-B11 at the end of this Appendix show the same distributions broken down by Source Area.

In reality, however, the Rest of U.S. is not just another city. Firstly, its constituent cities were quite varied, mostly consisting of Orlando, FL (21%), Oakland, CA (16%), Tacoma,WA (16%), Richmond, CA (7%), Holyoke, MA (4%), El Paso, TX (4%), and Fort Worth, TX (3%). And secondly, the contributions from these cities was uneven over time: for example, Fort Worth contributed over 1993-1994, Orlando and Richmond over 1996-2000, El Paso over 1999-2000, and Holyoke for only one year, 1996. In other words, the Rest of U.S. is a time-varying heterogeneous mixture, and this fact should be borne in mind when interpreting its results.

Table B3. Sample Size for Known Source Areas by City and Year

City	1993	1994	1995	1996	1997	1998	1999	2000	Total
Atlanta	17	21	17	28	11	29	18	20	161
Baltimore	5	3	14	30	23	37	35	25	172
Boston	15	22	18	19	18	10	25	19	146
Chicago	16	23	21	23	16	34	21	23	177
Dallas	21	17	9	1	11	19	27	24	129
Denver	20	29	26	26	30	43	24	27	225
Detroit	25	17	15	20	13	25	28	27	170
Houston	29	6	22	8	26	25	37	30	183
Los Angeles	21	7	21	26	26	39	18	25	183
Miami	11	9	18	22	24	21	23	9	137
New Orleans	5	2	8	19	17	20	13	19	103
New York	23	55	54	60	52	58	41	44	387
Newark	20	34	28	10	31	44	37	23	227
Philadelphia	10	28	30	38	36	42	34	39	257
Phoenix	27	17	35	30	27	40	39	21	236
San Diego	31	41	39	21	18	42	31	29	252
San Francisco	10	19	18	29	18	26	19	19	158
Seattle	6	15	30	16	26	17	26	20	156
St Louis	11	24	30	28	18	29	32	27	199
Washington DC	27	26	14	25	24	37	23	17	193
Rest Of US	9	14	21	43	44	59	68	56	314
Total	359	429	488	522	509	696	619	543	4165

A Multinomial Model for Heroin Flow

The outcome data consisted of counts (number of heroin transactions) distributed over four categories (Source Areas). The distribution of the counts was thought to depend on city and year. For example, in 1993 Atlanta had 17 heroin transactions, 0 from Mexico, 2 from South America, 13 from South East Asia, and 2 from South West Asia, so Atlanta's 1993 observed outcome was the vector of counts (0, 2, 13, 2), or equivalently, the vector of proportions (0, 0.12, 0.76, 0.12).

We modeled the counts via a multinomial model with generalized logit link functions (Agresti 1990, chapter 9). Thus in the *i*th city and *t*th time period, the population (or "true") proportion of heroin coming from the *j*th source was represented by:

$$p_{itj} = f(\alpha_j + city_{ij} + time_{tj}) = \exp(\alpha_j + city_{ij} + time_{tj})/\sum\exp(\alpha_j + city_{ij} + time_{tj}) \quad (1)$$

$$n_{itj} = n_{it}p_{itj} \sim \text{multinomial}\{n_{it}, (p_{it1}, p_{it2}, p_{it3}, p_{it4})\} \quad (2)$$

where n_{it} is the number of transactions in the *i*th city and *t*th year, and the summation in the denominator of (1) is over all j = 1 to 4 categories. For each category there are 28 parameters (20 for the 21 cities, 7 for the 8 years, and an intercept term), and thus 112 parameters in total.

As it stands, the model is over parameterized because the four proportions must add to one for a given city and year. This implies that once p_2, p_3, and p_4 are known then so is $p_1 = (1 - p_2 - p_3 - p_4)$. The most convenient solution is to set all 28 parameters associated with p_1 to zero, leaving 84 identifiable parameters in the model. This particular constraint makes (1) equivalent to fitting three simultaneous generalized logistic models:

$$\log(p_{it2}/p_{it1}) = \alpha_1 + city_{i1} + time_{t1} \quad (1.1)$$

$$\log(p_{it3}/p_{it1}) = \alpha_2 + city_{i2} + time_{t2} \quad (1.2)$$

$$\log(p_{it4}/p_{it1}) = \alpha_3 + city_{i3} + time_{t3} \quad (1.3)$$

The generalized logistic model is sensible for proportions since, for a given city and year, estimated proportions from each source are in the unit interval ($0 < p_j < 1$) and together they sum to one ($\sum p_j = 1$). An additional attraction of this model lies in the simple interpretation of its parameters in terms of multiplicative effects on the generalized odds, $o_{itj} = p_{itj}/p_{it1}$. In generic terms, if β_j is the parameter associated with predictor x_{ij} in the *j*th logistic equation (as in $\log(o_{ij}) = \log(p_{ij}/p_{i1}) = \alpha_j + \beta_j x_{ij}$) then a unit increase in x_{ij} shifts $\log(o_{ij})$ by β_j, and multiplies o_{ij} by $\exp(\beta_j)$. This, coupled with the absence of city-by-time interaction terms, permits quite general conclusions. Consider for example, the logit equation for South America, equation (1.1), which describes the effect of time and city on the odds of heroin arriving from South America (over Mexico). For this odds we are able to conclude: (i) For all cities, the odds was over 7 times higher in 2000 than in 1993; and (ii) For all years, the odds was over 31 times higher for Miami than for the Rest of U.S. We elaborate on these results in section 4.

Although the parameters are of some interest, in this study the primary interest lies in the proportion themselves. Equation (1) shows the relationship between estimated parameters and estimated proportions. As an illustration, for Atlanta in 1993 the observed vector of proportions from Mexico, South America, South East Asia, and South West Asia was (0, 0.12, 0.76, 0.12), and the corresponding vector of estimated population proportions was (p_1, p_2, p_3, p_4) = (0.04, 0.04, 0.82, 0.10). Similar estimates were obtained for all combinations of the 21 cities and 8 years, giving a total of 168 proportion vectors. Then for each year, a DAWN-based weighted average of the 21 city proportion vectors provided the estimated proportion vector for the Nation in that year. Estimates of city proportions and National proportions are displayed in sections 3 and 4, respectively.

The remainder of this section discusses various methodological issues related to the multinomial model above. Firstly, we consider alternative models: models with polynomial time and models with some form of city-by-time interaction. Secondly, we address the related problems of zero cells and data sparseness.

Polynomial Models

Model (1) treats time as a factor with eight levels, but alternatively time could be modeled smoothly by polynomial functions. Polynomial models have the potential to fit well with fewer parameters, and can also be used for forecasting if deterministic time trends seem appropriate. However, as Table B4 (column one) shows, polynomial models did not appear to be very useful for the retail heroin data. Linear, quadratic, and cubic polynomial models were distinctly inferior to model (1) (the discrete-time no-interaction model), and while the 4^{th} degree polynomial model had a comparable fit, this polynomial model seemed implausibly elaborate to model eight time points.

Table B4. AIC Statistics for Various Models

	No-interaction Model	Interaction Models		
		City-by-Time	3-Group-by-Time	2-Group-by-Time
Discrete Time:	3005	5704	2996	2978
Polynomial Time:				
Linear	3090	3091	3098	3095
Quadratic	3038	3048	3023	3022
Cubic	3028	3121	2989	2990
Quartic	3003	3259	2974	2965

Table B4 gives the Akaike Information Criterion (AIC) statistics for various models that will be discussed in this section, our immediate interest being on models without interactions (column 1).

The AIC statistic, defined as minus twice the loglikelihood plus twice the number of parameters in the model, is used to compare the fit of a set of models. The model with the smallest AIC is preferred, but two models having AIC statistics within a few units of each other should be judged to fit similarly. Note that the difference in AIC of two nested models is their likelihood ratio test statistic with an additional penalty for the more elaborate model.

Interaction Models

The effect of city and time in the above model has a simple additive structure on the scale of the generalized logits, or equivalently, a simple multiplicative structure on the scale of the generalized odds. This simplicity allowed the rather general conclusions mentioned above: *for all cities*, the odds of heroin arriving from South America (over Mexico) was over 7 times higher in 2000 than in 1993. We now attempt to justify the absence of an interaction between cities and time.

In passing, we note that the no-interaction model is not as restrictive as it might first seem. For example, the city-specific predictions presented in Figure B3 (section 4) have very different patterns on the scale of the proportions, yet these were actually based on model (1), a model with no interactions. This illustrates the point that a simple structure on the scale of the generalized logits does not imply a simple structure on the scale of the proportions (the scale of practical interest).

Two types of models with interactions were considered: city-by-time interactions and group-by-time interactions. The city-by-time interaction model (Table B4, column 2) added all 140 city-by-time interaction parameters to each of the three no-interaction generalized logistic models. This is an extremely large model with 504 parameters (three sets of [1 + 20 + 7 + 140]), which exacerbated the problems associated with of zero cells and sparse data discussed below. Firstly, the number of parameters is now an appreciable fraction (over 12%) of the sample size. Secondly, convergence is questionable because of the zero cells; indeed, convergence to a genuine maximum likelihood estimate is impossible for a saturated model even if *any* of the cells have zero counts (Agresti, 1990, p. 245).

We fit the model nevertheless (using weighted maximum likelihood described below) and obtained an AIC of 5704. This was incomparably worse than the no-interaction model (AIC = 3005), so the decision in favor of the simpler model was straightforward. We also experimented with city-by-time interaction models with polynomial time. Although these were far better than their discrete-time counterpart, they could not improve on the no-interaction model.

The second type of interaction model included group-by-time interactions (Table B4, columns 3 and 4), where the 21 cities were nested in one of three groups: the Western Pattern Group (9 cities), the Eastern Pattern Group (11 cities), and the Rest of U.S. (1 city). This model added only 14 parameters per logistic equation rather than the 140 added by the city-by-time interaction model. The rational for, and composition of, these groups is described later. For now we note that the nomenclature makes sense (the Western Pattern Group contains most of the western cities, and the Eastern Pattern Group contains most of the eastern cities), and the three groups had distinctly different heroin sources patterns based on the no-interaction model (Figure B3).

The 3-group interaction model gave an AIC of 2996 (Table B4, column 3) which is slightly better than the no-interaction model. However, this improvement was driven by the 1-city group, the Rest of U.S.. This was very evident from the predicted city generalized logit profiles: for a given logit, the Western and Eastern Pattern Groups were almost parallel, but quite different from the Rest of U.S. It was also confirmed by fitting a 2-group interaction model (Rest of U.S. versus the 20 MSAs) which gave an AIC of 2978 (Table B4, columns 4).

Although there is no question of the superior fit to the *sample data* of the 2-group interaction, we nevertheless preferred the simpler no-interaction model. This was because of reservations about the representativeness of the sample data for the Rest of U.S.. In particular, it seems likely that the 33 city composition of the Rest of U.S. has changed over time in way that exaggerates the substitution of South American heroin for Mexican heroin over 1993-2000. This points *against* giving the Rest of U.S. its own profile. To the contrary, it seems desirable to borrow the common profile of the 20 MSAs, which is exactly what the no-interaction model does.

Zeros and Sparseness

In this subsection we discuss two somewhat related data problems that can adversely affect estimation and inference of multinomial models. The first issue concerns the number and configuration of zero cells in the data set. The second concerns the sparseness of the data, or average sample size per cell.

The multinomial data set shown in supplementary tables B8-B11 contained 672 cells, being all combinations of 4 sources, 21 cities, and 8 years. Over half of the cells had zero transactions, and although these zero cells were distributed reasonably evenly over the sources (75-119), years (40-49), and cities (7-24), we did encounter problems with the nonexistence of maximum likelihood estimates.

Formally, this difficulty arises when the only solution to the likelihood equations includes an estimated population proportion of zero, a value that is not strictly compatible with the generalized logistic model (Haberman, 1974; Agresti, 1990, p. 245). In practice, the estimated proportion is trying to go to zero, so the corresponding parameters on the scale of the generalized logits take on very small or very large values. This is evident from the parameter estimates for our model in Table B15.

Our approach was to replace a zero cell by a count of one and a weight of 0.001, and use weighted maximum likelihood rather than ordinary maximum likelihood (nonzero cells were given weights of 1). This method avoids the detection of problems, but has a negligible effect on the estimated proportions. In fact, this amounts to a formal exercise in avoiding the detection of a formal "nonexistence" problem. In effect, estimated proportions arbitrarily close to zero are accepted as zero, even though zero is formally excluded from the model. Haberman (1974) has called such limiting cases "extended" maximum likelihood estimates

The above deals with the zero problem from the point of view of estimation. However, there are also concerns for inference which are not as easily sidestepped. In particular, it is likely that likelihood ratio (and other) test statistics are poorly approximated by chi-squared distributions. Although this is not of central importance in this study, it does mean that our reported p-values should be interpreted rather loosely.

We now discuss the problem of data sparseness. Since the data set contained 4165 heroin transactions distributed over 672 cells, there was an average of 6 observations per cell. Such a data set is somewhat sparse, but not unduly so. In any case, of more relevance is the number of observations per model parameter, which was a respectable 50 = 4165/84.

Some evidence for this statement was obtained by comparing estimates obtained from our fixed effects model, where each city had a separate intercept parameter, with those from a random effects model, where the distribution of city intercepts was modeled more parsimoniously. The results were very similar even though the fixed effects model had three times the number of parameters (84 = 3 sets of [1 + 20 + 7] to 27 = 3 sets of [1 + 1 + 7]).

A Model for Weights

As previously noted, the multinomial model provided an estimate for the vector of population proportions for all combinations of the 21 cities and 8 years, giving a total of 168 proportion vectors.

Then, for each year, a DAWN-based weighted average of the 21 city proportion vectors provided the estimate for the proportion vector for the Nation. Weighting was necessary because, as shown in Table B5, the DMP database was not representative of drug purchases across the U.S. For example, DMP over-represents heroin purchases in Atlanta (3.87% rather than 0.61%) and under-represents those in New York (9.29% rather than 15.03%). A particularly notable under-representation applied to the conglomeration of the Rest of U.S., which occurs because the DMP program is largely based in the large Metropolitan Statistical Areas.

Table B5. DAWN weights versus DMP weights (averaged over 1993-2000)

City	DAWN Weight	DMP Weight
Atlanta	0.61	3.87
Baltimore	10.41	4.13
Boston	3.98	3.51
Chicago	10.64	4.25
Dallas	0.59	3.10
Denver	0.69	5.40
Detroit	4.01	4.08
Houston	0.73	4.39
Los Angeles	4.40	4.39
Miami	0.83	3.29
New Orleans	0.59	2.47
New York	15.03	9.29
Newark	7.18	5.45
Philadelphia	5.37	6.17
Phoenix	1.04	5.67
San Diego	1.43	6.05
San Francisco	4.68	3.79
Seattle	3.44	3.75
St Louis	0.80	4.78
Washington DC	2.47	4.63
Rest Of US	21.09	7.54

Weighting seeks to remedy the lack of representativeness in DMP. The desired weight for a given city in a given year is the proportion of U.S. purchases made in that city and year. We estimated the proportion of purchases via a surrogate variable, the proportion of drug-related emergency room visits. The emergency event data was obtained from the Drug Abuse Warning Network (DAWN) database, which was compiled by the Substance Abuse and Mental Health Services Administration (SAMHSA) on a semi-annual basis over the period 1988-1999 for 21 large U.S. cities and the Rest of U.S.

Except for Houston, all cities in DAWN were also in DMP. To enable us to use Houston's DMP data, we added Houston to DAWN by pairing it with Dallas, a broadly similar city. The ratio of the two cities' emergency-event counts were then made proportional to the ratio of their populations. To smooth over the random fluctuations in DAWN, we fit a loglinear Poisson regression model to the resulting "extended" DAWN database (18 semi-annual emergency-event counts from 1988-2000 for each city), and thus obtained estimated counts, and subsequently weights, for 1993-2000.

Figures B1 and B2 show the resulting DAWN-based weights. We grouped the cities into two groups corresponding to their heroin source patterns. Because the two patterns were largely, respectively, western and eastern cities, we refer to them as the *Western Pattern Group* and *Eastern Pattern Group*. The Western Pattern Group actually comprised Dallas, Denver, Houston, Los Angeles, Phoenix, San Diego, San Francisco, Seattle, and St Louis, while the Eastern Pattern Group comprised Atlanta, Baltimore, Boston, Chicago, Detroit, Miami, New Orleans, New York, Newark, Philadelphia, and Washington DC. The Rest of U.S. conglomeration was not in either group, but for convenience is plotted on the graph of the Western Pattern Group.

The important point to note from the Figures B1 and B2 is the dominance of the Eastern Pattern Group (average weight 61%) over the Western Pattern Group (average weight 18%). Indeed, this relative dominance increased by 33% over 1993-2000: the Eastern Pattern Group's weight increased from 59% to 63%, while the Western Pattern Group's weight decreased from 20% to 16%. Meanwhile, the Rest of U.S. accounted for the residual weight, a constant 21%.

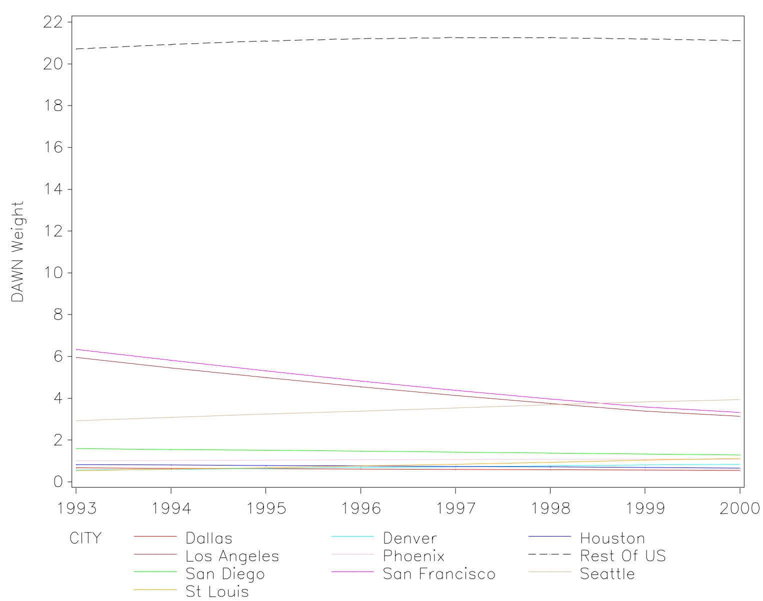


Figure B1: DAWN Weights: Western Pattern Group Cities and Rest of U.S.

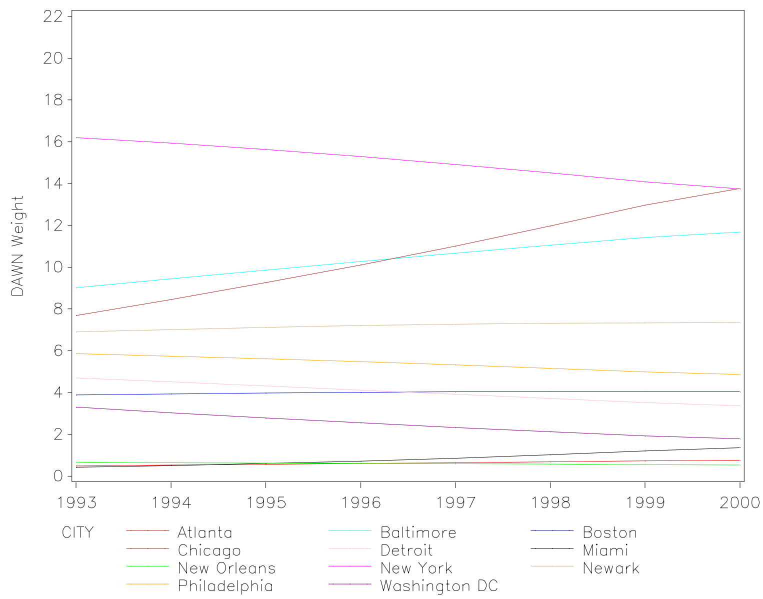


Figure B2: DAWN Weights: Eastern Pattern Group Cities

Regional Results

Parameter estimates for the generalized logistic model are given in supplementary appendix Table B15. The first three columns give parameter estimates, and lower and upper 95% confidence limits, for the South American logistic equation. Analogous results are given in columns 4-6, and columns 7-9 for the South East Asian and South West Asian logistic equations, respectively. Parameter estimates are expressed in terms of differences from the reference city (Rest of U.S.) and reference year (1993).

We illustrate the interpretation of these parameter estimates for the South American logistic equation (1.1 above). The parameter estimate associated with the year 2000 in the South American logistic equation was 1.99, with lower and upper confidence limits of 1.08 and 2.91 respectively. Thus the odds of heroin coming from South America (over Mexico) was exp(1.99) = 7.35 times higher in 2000 than in 1993, and the 95% confidence interval was between exp(1.08) = 2.93 and exp(2.91) = 18.43. This result applies to all cities since the model does not include city-by-time interaction terms. The confidence interval is wide but excludes one, so the increase in the South American heroin proportion relative to the Mexico proportion is statistically significant ($p<0.0001$).

Similar interpretations can be obtained for cities. For example, the estimated parameter associated with Miami in the South American equation was 3.44 with confidence limits of 2.62 and 4.26. Thus, for all years, the odds of heroin coming from South America (over Mexico) was exp(3.44) = 31.19 times higher in Miami than for the Rest of U.S. The confidence interval is between 13.71 and 70.86, so the result is statistically significant (again, $p<0.0001$).

We now turn to the estimated proportions of heroin by Source Area. Figure B3 shows the relevant city-specific time profiles for Mexico, South America, South East Asia, and South West Asia. To accentuate the major patterns, each city is given a "group" color. The red and blue lines represent the Western and Eastern Pattern Groups, respectively, while the Rest of U.S. is represented by the dashed black line. We note that individual cities can be identified in Figures B6-B13 in the supplementary figures section to this appendix.

The main features to emerge from Figure B3 are as follows. Firstly, in the last six years, almost all heroin consumed in the Western Pattern Group came from Mexico, although up to 10% came from South East Asia in 1993-1994. Thus the only change over time has been the replacement of South East Asian heroin with Mexico heroin.

Secondly, the vast majority of heroin consumed in the Eastern Pattern Group came from either South America or South East Asia. The residual proportion (up to 20%) came from Mexico and South West Asia. The most striking temporal pattern for the Eastern Pattern Group has been the substitution of South American heroin for South East Asian heroin. Over the eight year period, the contribution from South East Asia has declined from between 30% and 90% to less 10%. Following a sharp decline in 1994, the proportion of heroin coming from South West Asia appears to be increasing. Both of these impressions are statistically significant: for example, the odds of heroin coming from South West Asian was 5.9 times higher in 1993 than 1994 ($p=0.002$), and 2.7 times higher in 2000 than in 1999 ($p=0.014$).

Thirdly, the patterns for the Rest of U.S. appear to be quite different from those of the two large groups. The pattern for South America is more like the Eastern Pattern Group, that for South East Asia is more like the Western Pattern Group, and those for Mexico and South West Asia are in between the two groups. Broadly speaking though, it seems reasonable to interpret the levels for the Rest of U.S. as being in somewhere "in between" those of the two large groups. And, of course, this much should be expected since the Rest of U.S. is a indeed a mixture of western and eastern cities.

On the other hand, we caution against over interpreting the profile shapes for the Rest of U.S. for the reason that the composition of the mixture of its cities may have varied over time. This possibility is suggested by Table B6, which shows the counts from all sources from the seven largest contributors to the Rest of U.S. All transactions from Orlando and Holyoke came from South America (64 and 11) or South East Asia (1 and 2), and these two cities joined the sample in 1995. On the other hand, all transactions from the other five cities came from Mexico, and cities from this group dominated the sample over 1993-1994. This particular sampling history would presumably exaggerate the substitution of South American heroin for Mexican heroin over 1993-2000.

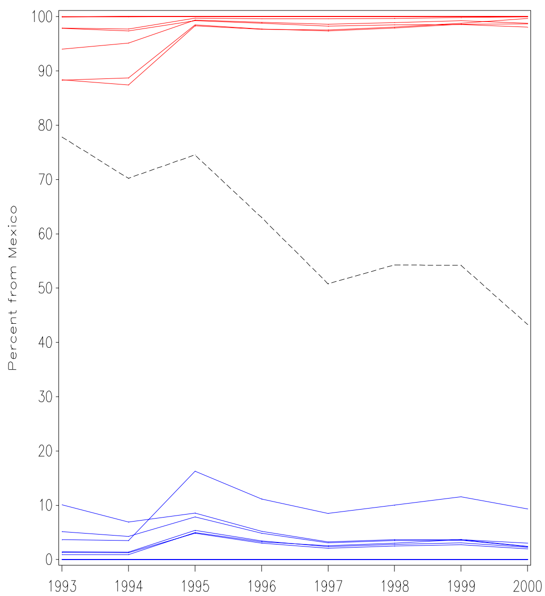


Figure B3a: Mexico

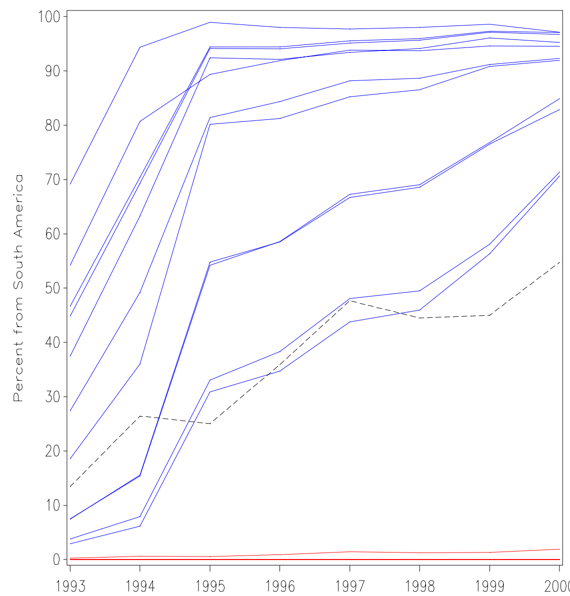


Figure B3b: South America

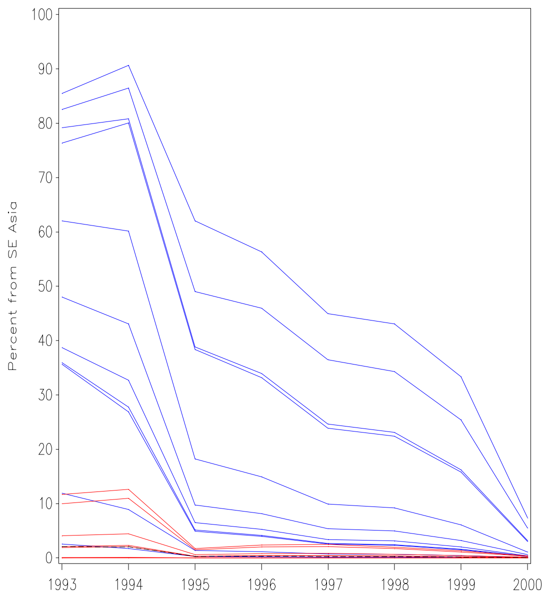


Figure B3c: South East Asia

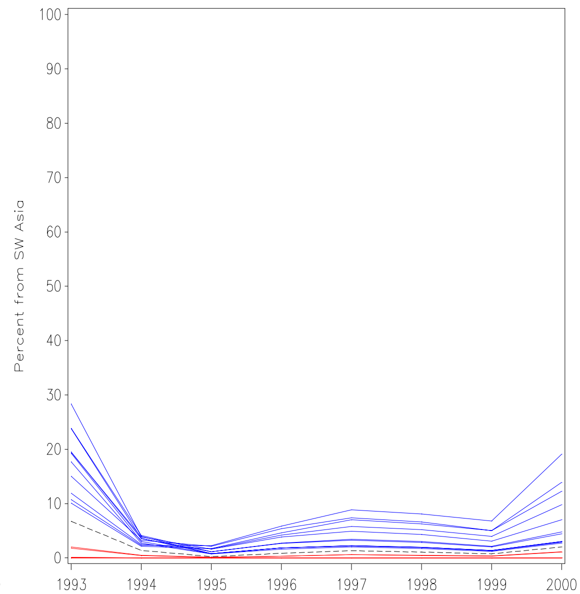


Figure B3d: South West Asia

Figure B3: Proportion of Retail Heroin Consumed in U.S. by Source Area: (a)Mexico, (b)South America, (c)South East Asia, (d)South West Asia. (Red = Western Pattern Group, Blue = Eastern Pattern Group, Black Dashed = Rest of U.S.)

Table B6. Counts from All Sources from the Seven Largest Cities in the Rest of U.S.

City	1993	1994	1995	1996	1997	1998	1999	2000	Total
Orlando, FL	0	0	0	2	12	22	12	17	65
Oakland, CA	3	2	11	6	7	11	9	0	49
Tacoma, WA	2	4	4	7	9	7	10	6	49
Richmond, CA	0	0	0	2	1	9	3	8	23
El Paso, TX	0	0	0	0	0	0	6	8	14
Holyoke, MA	0	0	0	13	0	0	0	0	13
Fort worth, TX	2	6	0	0	0	0	0	0	8
Total	7	12	15	30	29	49	40	39	221

National Results

In each year, the DAWN-based weighted average of the 21 city proportions provided an estimate of the heroin source proportions for the Nation. These are shown in Figure B4 for the years 1993-2000. The main features are predictable from the results on city-specific estimates and DAWN weights described above.

Firstly, there has been a marked trend for the Nation as a whole to substitute South American heroin for South East Asian heroin. This substitution was largely driven by the Eastern Pattern Group. However, all groups have played a role: the Western Pattern Group's consumption of South East Asia heroin evaporated after 1994, while the Rest of U.S. steadily increased its consumption of South American heroin over 1993-2000.

Secondly, there has been a mild decline in the Mexican proportion over 1993-2000. This is partly due to the considerable reduction in this proportion for the Rest of U.S., and slight reduction for the Eastern Pattern Group. It was also partly due to the declining market share of the Western Pattern Group over the period (from 20% to 16%) at the expense of the increasing share of the Eastern Pattern Group (from 59% to 63). On the other hand, we know it was not due to a decline in Mexican heroin consumption within the Western Pattern Group (Figure B3).

Thirdly, the South West Asian profile for the Nation very much mirrors the corresponding profiles for the cities making up the Eastern Pattern Group. Following a sharp decline in 1994, the proportion of heroin coming from South West Asia eventually picked, certainly by 2000. The proportion is low, but noticeable.

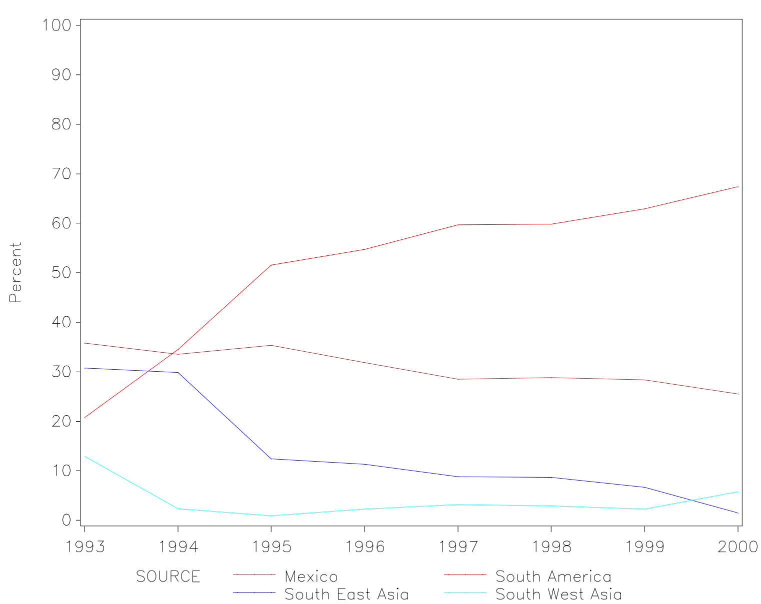


Figure B4: Proportion of Heroin consumed in U.S. by Source

Limitations

We close the section on the sources of U.S. retail heroin by highlighting three limitations associated with the above results: (i) The exclusion from our analysis of the Heroin Signature Program data due to the unreliability of its retail purchase identifiers; (ii) The possibility that the "Rest of U.S." is not a random sample from the rest of the U.S.; and (iii) The exclusion from our analysis of almost 2,000 transactions of an unknown source.

As stated, these are limitations in the data rather than the model, but in some cases – particularly for the unknown source problem – additional modeling could compensate for weak data. In either event, whether the improvements come from data or models, these issues require further investigation.

Data from the Heroin Signature Program

Although our analysis was based exclusively on heroin purchases from the domestic monitoring program (DMP), we had originally intended to augment the sample with data from the Heroin Signature Program (HSP). Since HSP extends over the entire country, this would have provided a much needed source of additional data from the Rest of U.S..

However, using HSP seemed inadvisable given the unreliability of fields necessary to identify retail purchases. Of the 6646 observations in the 1993-2000 HSP database, 1157 were designated as "purchases", and 48 of these were "retail", having prices of $200 or less. However, 35 of the 48 had an associated price of zero, but a mean size of 27 pure grams, and those with positive prices had a mean size of 25 pure grams (all but three cost less than $100 per pure gram). These transaction sizes are orders of magnitude higher than typical retail levels, where a $200 purchase might fetch between 0.1 to 0.2 pure grams. In short, while it is possible that HSP contains useful retail purchase data, we were unable to extract it.

The Drug Monitoring Program and the Rest of U.S.

Although the DMP is based mainly in large Metropolitan Statistical Areas, cities from the Rest of U.S. are also included. However, the sampling mechanism for these cities is insufficiently clear. Our stratified approach effectively requires a random sample of transactions within each of the 21 "cities", but it is not at all clear that this is a warranted assumption for the Rest of U.S. In particular, it seems likely that the city composition of the Rest of U.S. has changed over time in way that exaggerates the substitution of South American heroin for Mexican heroin over 1993-2000. If so, this exaggeration would carry over to the National estimates in Figure B4.

Purchases from Unknown Sources

The results we have presented were based on the 4165 retail purchases coming from a *known* source. As Table B2 showed, however, there were 1917 additional transactions (32% of the sample) whose source was unknown: 663 were of an insufficient magnitude to assay, 739 could be assayed but the resulting signature could not be matched to a known signature, and 515 were just missing.

Table B7 summarizes facts about the size and purity of heroin for the known and unknown categories. The Sufficient but Unknown category has similar size and purity to the known categories, as expected. The Missing category has a markedly lower purity, and is what we would expect for transactions of insufficient size and/or purity to assay. However, the Insufficient to Assay category itself does not have an unusually low purity or size. This incongruity should be investigated in future work.

Table B7. Average Transaction Size and Purity for Known and Unknown Sources

Source	Sample Size	Bulk Grams	Purity	Pure Grams
Mexico	1916	1.14	27.59	0.26
South America	1721	0.79	52.24	0.29
South East Asia	420	0.65	36.85	0.19
South West Asia	108	0.80	39.05	0.20
Sufficient but Unknown	739	0.81	35.86	0.19
Insufficient to Assay	663	1.19	29.02	0.16
Missing	515	1.18	1.09	0.01

Ignoring transactions from an unknown source amounts to treating them as "missing at random". This implies that the proportion vector for known sources is the same as that for unknown sources. Although this assumption may be reasonable for transactions that are genuinely of insufficient size and/or purity to assay, it is by no means clear that it applies to the Sufficient but Unknown category. For example, if Mexican heroin is easier to identify than heroin from other sources, then a Sufficient but Unknown transaction is unlikely to be Mexican. Indeed, there is some evidence to support this particular possibility: cities with high Mexican proportions in their known sample tend to have few Sufficient but Unknown transactions.

This scenario is merely a possibility, but we proceed to illustrate a way forward. Clearly the entire issue of unknown sources should be addressed more seriously in future work. For the time being, we assume that no transactions in the Sufficient but Unknown category are Mexican, and that all others are missing at random. Further (ignoring the above incongruities in the data), we treat the Insufficient to Assay category as its name indicates, and add to it the Missing category (since these transactions actually appear to be of insufficient size and/or purity to assay). Thus we are now supposing that there are 1178 transactions in the Insufficient to Assay category, all missing at random, and 739 transactions in the Sufficient but Unknown category, none from Mexico, but otherwise missing at random.

Our approach is as follows: (i) Model the proportions based on the known sample of 4165 (these are the results obtained earlier); (ii) Distribute the 739 Sufficient but Unknown transactions over the modeled proportions, but modified such that Mexico receives a zero probability; (iii) Re-model the augmented data (the known and imputed sample), and apply the DAWN-weights. The resulting estimates for the Nation are shown in Figure B5. As expected, the shapes are reasonably similar to those in Figure B4, but the level of the Mexican profile decreases, while the levels of the other three sources increase.

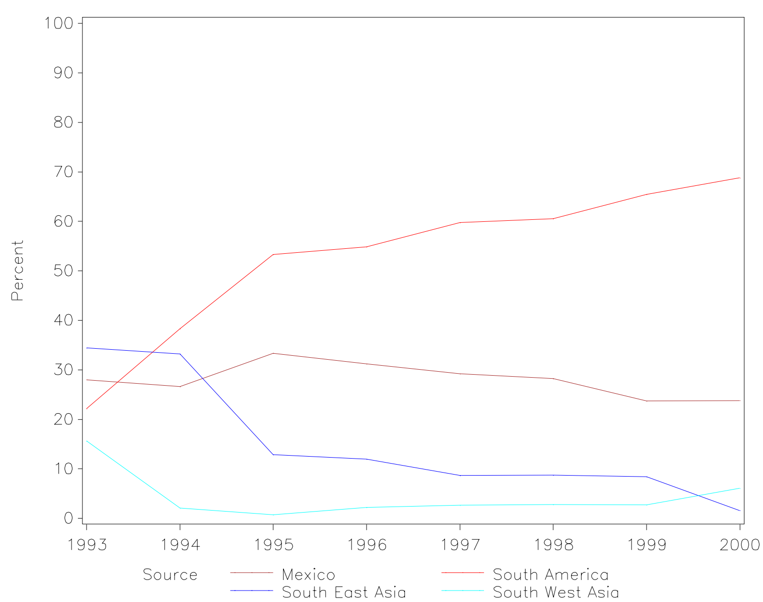


Figure B5: Proportion of Heroin consumed in U.S. by Source: Imputed Unknown

To illustrate the details, consider the Rest of U.S. in 2000. There were 56 transactions from a known source (26 Mexico, 29 South America, 0, South East Asia, and 1 South West Asia), and 16 transactions from the Sufficient but Unknown category. The vector of modeled proportions was (0.43, 0.55, 0, 0.02), which when modified to exclude Mexico is (0, 0.96, 0, 0.04). The modification entails setting the Mexican proportion to zero and upweighting the other three so they sum to one. Now, distributing the 16 unknowns over the vector of modified modeled proportions gave a vector of imputed counts of (0, 15.43, 0.01, 0.56), which when rounded and added to the vector of known counts, (26, 29, 0, 1), gave the augmented vector of counts of (26, 44, 0, 2). Similar augmented count vectors were obtained for all cities in all years, and the multinomial model was estimated again to obtain a new vector of modeled proportions of (0.36, 0.61, 0, 0.03). The effect, of course, was to downweight Mexico and upweight the other three sources.

References

Agresti, A. (1990). Categorical Data Analysis. New York: John Wiley.

Haberman S. J. (1974). The Analysis of Frequency Data. Chicago: University of Chicago Press.

Appendix B - Supplementary Tables

Table B8. Sample Size by City and Year: Source Area: Mexico

CITY	1993	1994	1995	1996	1997	1998	1999	2000	Total
Atlanta	0	0	3	11	0	0	1	0	15
Baltimore	0	0	0	0	0	0	0	0	0
Boston	0	0	0	0	0	0	0	0	0
Chicago	1	0	0	0	3	1	0	0	5
Dallas	21	17	9	1	10	18	26	24	126
Denver	20	29	26	26	30	43	24	27	225
Detroit	0	0	0	4	0	0	0	0	4
Houston	28	6	22	8	26	25	35	30	180
Los Angeles	20	2	21	26	26	39	18	25	177
Miami	0	0	1	0	0	1	5	0	7
New Orleans	0	0	0	0	0	4	0	0	4
New York	0	0	0	0	0	0	0	0	0
Newark	0	0	0	0	0	0	0	0	0
Philadelphia	0	0	0	0	0	0	0	0	0
Phoenix	27	17	35	30	27	40	39	21	236
San Diego	31	41	39	21	18	42	31	29	252
San Francisco	10	19	17	29	18	26	19	19	157
Seattle	6	15	30	16	26	17	26	20	156
St Louis	7	22	29	28	18	29	32	27	192
Washington DC	0	0	0	0	4	0	0	1	5
Rest Of US	9	14	20	18	18	32	38	26	175
Total	180	182	252	218	224	317	294	249	1916

Table B9. Sample Size by City and Year: Source Area: South America

CITY	1993	1994	1995	1996	1997	1998	1999	2000	Total
Atlanta	2	4	5	3	8	18	7	16	63
Baltimore	1	3	13	21	20	31	33	22	144
Boston	4	17	17	17	18	10	25	19	127
Chicago	1	0	3	9	5	16	14	19	67
Dallas	0	0	0	0	0	0	0	0	0
Denver	0	0	0	0	0	0	0	0	0
Detroit	0	4	9	10	11	16	22	22	94
Houston	0	0	0	0	0	0	2	0	2
Los Angeles	0	0	0	0	0	0	0	0	0
Miami	5	9	17	22	24	18	18	9	122
New Orleans	1	1	8	17	14	14	13	19	87
New York	13	31	49	58	46	54	41	41	333
Newark	11	22	27	9	29	42	36	22	198
Philadelphia	4	26	30	38	36	42	33	39	248
Phoenix	0	0	0	0	0	0	0	0	0
San Diego	0	0	0	0	0	0	0	0	0
San Francisco	0	0	0	0	0	0	0	0	0
Seattle	0	0	0	0	0	0	0	0	0
St Louis	0	0	0	0	0	0	0	0	0
Washington DC	4	6	12	14	9	29	17	11	102
Rest Of US	0	0	0	23	26	26	30	29	134
Total	46	123	190	241	246	316	291	268	1721

Table B10. Sample Size by City and Year: Source Area: South East Asia

CITY	1993	1994	1995	1996	1997	1998	1999	2000	Total
Atlanta	13	17	9	14	3	8	9	0	73
Baltimore	3	0	1	6	1	5	2	2	20
Boston	6	5	1	2	0	0	0	0	14
Chicago	14	23	18	13	3	13	6	1	91
Dallas	0	0	0	0	1	0	1	0	2
Denver	0	0	0	0	0	0	0	0	0
Detroit	22	11	6	6	2	9	2	1	59
Houston	1	0	0	0	0	0	0	0	1
Los Angeles	1	5	0	0	0	0	0	0	6
Miami	3	0	0	0	0	0	0	0	3
New Orleans	3	1	0	0	2	2	0	0	8
New York	4	23	4	1	4	2	0	0	38
Newark	4	10	1	1	2	2	1	0	21
Philadelphia	1	0	0	0	0	0	0	0	1
Phoenix	0	0	0	0	0	0	0	0	0
San Diego	0	0	0	0	0	0	0	0	0
San Francisco	0	0	1	0	0	0	0	0	1
Seattle	0	0	0	0	0	0	0	0	0
St Louis	4	2	0	0	0	0	0	0	6
Washington DC	23	19	1	10	10	7	4	1	75
Rest Of US	0	0	1	0	0	0	0	0	1
Total	102	116	43	53	28	48	25	5	420

Table B11. Sample Size by City and Year: Source Area: South West Asia

CITY	1993	1994	1995	1996	1997	1998	1999	2000	Total
Atlanta	2	0	0	0	0	3	1	4	10
Baltimore	1	0	0	3	2	1	0	1	8
Boston	5	0	0	0	0	0	0	0	5
Chicago	0	0	0	1	5	4	1	3	14
Dallas	0	0	0	0	0	1	0	0	1
Denver	0	0	0	0	0	0	0	0	0
Detroit	3	2	0	0	0	0	4	4	13
Houston	0	0	0	0	0	0	0	0	0
Los Angeles	0	0	0	0	0	0	0	0	0
Miami	3	0	0	0	0	2	0	0	5
New Orleans	1	0	0	2	1	0	0	0	4
New York	6	1	1	1	2	2	0	3	16
Newark	5	2	0	0	0	0	0	1	8
Philadelphia	5	2	0	0	0	0	1	0	8
Phoenix	0	0	0	0	0	0	0	0	0
San Diego	0	0	0	0	0	0	0	0	0
San Francisco	0	0	0	0	0	0	0	0	0
Seattle	0	0	0	0	0	0	0	0	0
St Louis	0	0	1	0	0	0	0	0	1
Washington DC	0	1	1	1	1	1	2	4	11
Rest Of US	0	0	0	2	0	1	0	1	4
Total	31	8	3	10	11	15	9	21	108

Table B12. Sample Size by City and Year: Source Area: Sufficient but Unknown

CITY	1993	1994	1995	1996	1997	1998	1999	2000	Total
Atlanta	30	14	2	1	1	3	3	4	58
Baltimore	4	0	7	4	0	5	4	4	28
Boston	20	16	3	1	4	2	1	1	48
Chicago	5	2	1	1	1	6	8	5	29
Dallas	3	4	2	0	0	1	6	2	18
Denver	11	13	1	0	0	5	5	1	36
Detroit	20	14	10	1	6	7	3	5	66
Houston	3	2	0	0	0	0	3	0	8
Los Angeles	3	1	0	1	1	1	7	0	14
Miami	37	1	3	1	0	2	5	1	50
New Orleans	12	7	0	2	5	3	4	5	38
New York	31	32	8	11	2	6	2	4	96
Newark	15	12	6	1	4	4	5	5	52
Philadelphia	10	10	7	1	0	6	5	1	40
Phoenix	13	8	3	0	1	0	2	0	27
San Diego	4	1	1	0	1	2	1	2	12
San Francisco	4	2	1	0	0	0	1	3	11
Seattle	2	2	2	0	0	0	3	1	10
St Louis	10	5	0	5	1	0	3	1	25
Washington DC	14	10	3	4	2	3	1	2	39
Rest Of US	2	8	1	2	1	2	2	16	34
Total	253	164	61	36	30	58	74	63	739

Table B13. Sample Size by City and Year: Source Area: Insufficient to Assay

CITY	1993	1994	1995	1996	1997	1998	1999	2000	Total
Atlanta	0	8	14	14	7	12	6	8	69
Baltimore	0	0	8	4	1	4	0	0	17
Boston	0	2	19	14	12	21	13	4	85
Chicago	0	8	9	8	4	9	10	3	51
Dallas	0	3	18	9	8	3	0	1	42
Denver	0	1	9	3	0	1	0	1	15
Detroit	0	2	10	6	11	6	6	3	44
Houston	0	1	1	0	1	9	1	0	13
Los Angeles	0	2	4	2	3	0	2	0	13
Miami	0	7	9	16	3	11	8	5	59
New Orleans	0	0	3	12	6	15	5	9	50
New York	0	3	10	6	4	3	2	3	31
Newark	0	1	1	3	1	2	2	1	11
Philadelphia	0	2	1	4	0	0	0	0	7
Phoenix	0	9	2	0	2	0	0	0	13
San Diego	0	0	0	1	0	0	1	0	2
San Francisco	0	2	2	2	3	1	2	0	12
Seattle	0	0	2	1	1	2	0	3	9
St Louis	0	0	3	3	2	1	4	1	14
Washington DC	0	5	13	12	4	3	5	3	45
Rest Of US	0	2	0	9	29	8	6	7	61
Total	0	58	138	129	102	111	73	52	663

Table B14. Sample Size by City and Year: Source Area: Missing

CITY	1993	1994	1995	1996	1997	1998	1999	2000	Total
Atlanta	1	2	4	6	0	2	4	4	23
Baltimore	1	1	2	2	4	2	1	2	15
Boston	0	0	3	1	1	1	2	0	8
Chicago	0	5	3	8	10	2	1	3	32
Dallas	1	5	1	5	18	0	9	9	48
Denver	0	1	2	4	0	0	1	0	8
Detroit	1	0	4	2	0	7	2	1	17
Houston	0	1	0	0	1	1	1	1	5
Los Angeles	0	1	1	0	0	6	9	2	19
Miami	9	1	4	1	2	7	8	1	33
New Orleans	15	2	2	3	2	3	5	1	33
New York	2	1	5	3	9	17	18	21	76
Newark	0	0	0	2	0	1	0	1	4
Philadelphia	0	1	2	1	0	0	1	1	6
Phoenix	3	1	0	0	0	0	0	0	4
San Diego	0	0	0	9	8	4	3	0	24
San Francisco	2	0	5	0	4	11	12	4	38
Seattle	2	2	2	6	2	3	5	2	24
St Louis	5	2	4	4	17	10	2	0	44
Washington DC	0	2	3	4	1	4	3	3	20
Rest Of US	0	1	0	5	7	3	9	9	34
Total	42	29	47	66	86	84	96	65	515

Table B15. Generalized Logistic Model Parameter Estimates

	SA/Mexico Equation			SEA/Mexico Equation			SWA/Mexico Equation		
Variable	Est	Lower	Upper	Est	Lower	Upper	Est	Lower	Upper
Intercept	-1.76	-2.59	-0.93	-3.63	-5.69	-1.57	-2.45	-3.68	-1.21
Atlanta	1.80	1.18	2.42	6.75	4.70	8.81	3.47	2.18	4.76
Baltimore	10.13	-11.77	32.03	13.21	-8.78	35.20	10.87	-11.07	32.80
Boston	10.30	-11.61	32.21	11.90	-10.10	33.91	10.02	-11.93	31.97
Chicago	2.93	1.98	3.87	8.18	6.01	10.36	4.93	3.49	6.36
Dallas	-9.34	-31.25	12.58	0.48	-1.95	2.91	-1.42	-3.63	0.80
Denver	-9.87	-31.76	12.02	-5.52	-27.52	16.49	-6.60	-28.54	15.34
Detroit	3.53	2.49	4.56	7.73	5.51	9.96	4.92	3.42	6.43
Houston	-4.17	-5.59	-2.76	-0.31	-3.11	2.48	-6.57	-28.51	15.37
Los Angeles	-9.68	-31.59	12.22	1.60	-0.54	3.75	-6.42	-28.35	15.52
Miami	3.44	2.62	4.26	3.80	1.39	6.20	3.31	1.75	4.86
New Orleans	3.43	2.39	4.47	5.86	3.54	8.19	3.78	2.06	5.50
New York	11.18	-10.43	32.78	13.08	-8.61	34.77	11.41	-10.22	33.04
Newark	10.69	-11.18	32.56	12.34	-9.62	34.30	10.53	-11.37	32.44
Philadelphia	10.87	-11.00	32.74	9.43	-12.61	31.48	10.67	-11.24	32.57
Phoenix	-9.88	-31.77	12.00	-5.46	-27.47	16.54	-6.64	-28.58	15.30
San Diego	-9.90	-31.77	11.98	-5.79	-27.79	16.22	-6.76	-28.70	15.18
San Francisco	-9.52	-31.43	12.39	-0.22	-3.01	2.57	-6.14	-28.08	15.79
Seattle	-9.54	-31.45	12.37	-4.88	-26.88	17.12	-6.05	-27.98	15.89
St Louis	-9.73	-31.63	12.17	1.45	-0.69	3.59	-1.46	-3.67	0.74
Washington DC	3.41	2.48	4.35	7.64	5.46	9.81	4.56	3.10	6.02
1994	0.78	-0.22	1.78	0.09	-0.85	1.03	-1.50	-2.70	-0.31
1995	0.67	-0.31	1.64	-2.02	-2.98	-1.06	-3.28	-4.77	-1.80
1996	1.20	0.29	2.11	-1.70	-2.60	-0.81	-1.90	-3.00	-0.80
1997	1.70	0.77	2.62	-1.66	-2.61	-0.72	-1.22	-2.31	-0.12
1998	1.56	0.67	2.45	-1.89	-2.77	-1.01	-1.49	-2.51	-0.47
1999	1.57	0.68	2.47	-2.34	-3.27	-1.40	-1.86	-2.96	-0.75
2000	1.99	1.08	2.91	-3.66	-4.89	-2.42	-0.63	-1.64	0.39

NOTE: Parameter estimates are on the log odds scale and are expressed in terms of differences from the reference city (Rest of U.S.) and reference year (1993). For example, the difference between 2000 and 1993 with respect to $\log(o_1) = \log(p_1/p_4)$ was 1.99, where p_1 is the heroin proportion from South America and p_4 is the heroin proportion from Mexico. Thus the odds of heroin coming from South America (over Mexico) was exp(1.99) = 7.35 times higher in 2000 than in 1993.

Appendix B – Supplementary Figures

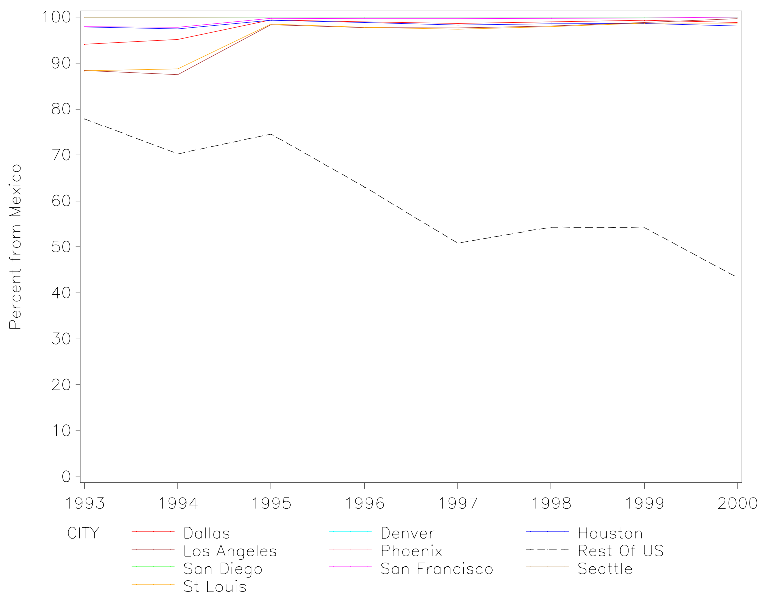


Figure B6: Proportion of Heroin from Mexico: Western Pattern and Rest of U.S.

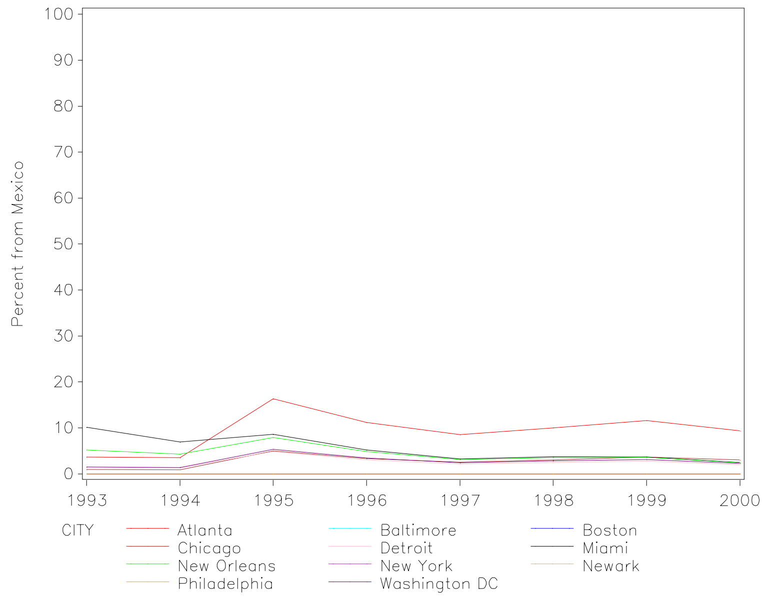


Figure B7: Proportion of Heroin from Mexico: Eastern Pattern

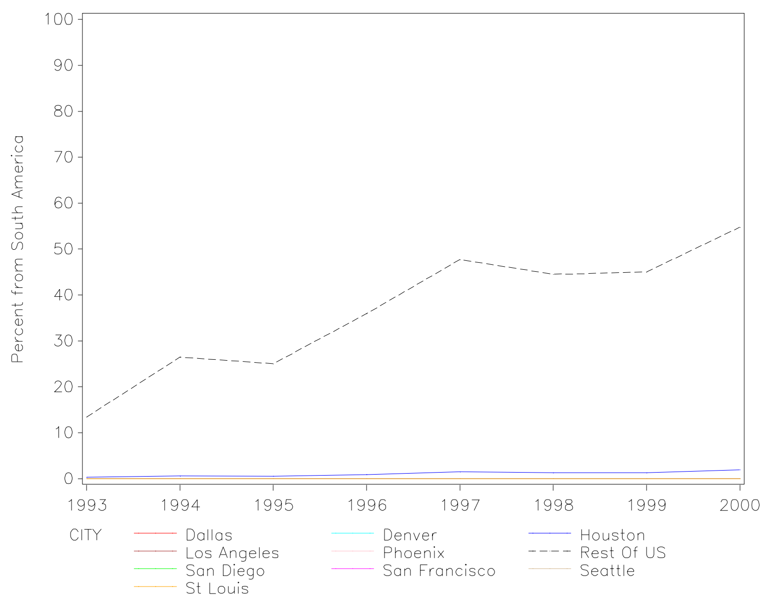


Figure B8: Proportion of Heroin from South America: Western Pattern and Rest of U.S.

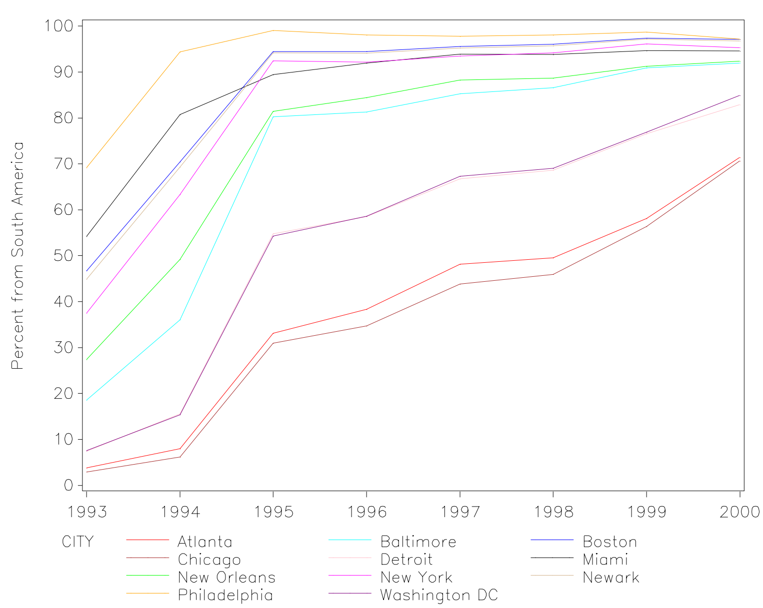


Figure B9: Proportion of Heroin from South America: Eastern Pattern

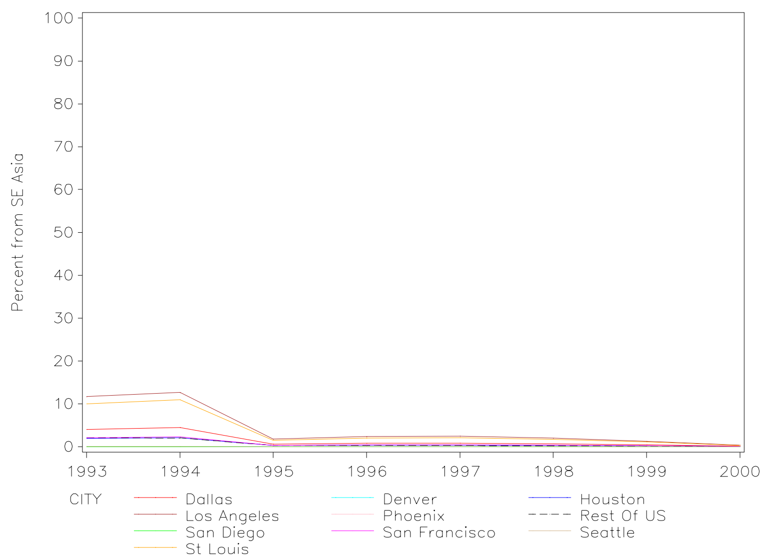


Figure B10: Proportion of Heroin from South East Asia: Western Pattern and Rest of U.S.

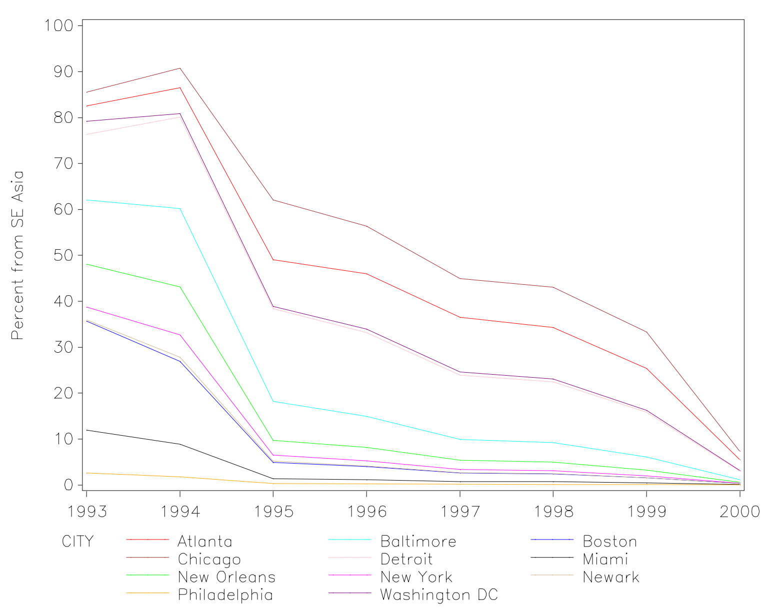


Figure B11: Proportion of Heroin from South East Asia: Eastern Pattern

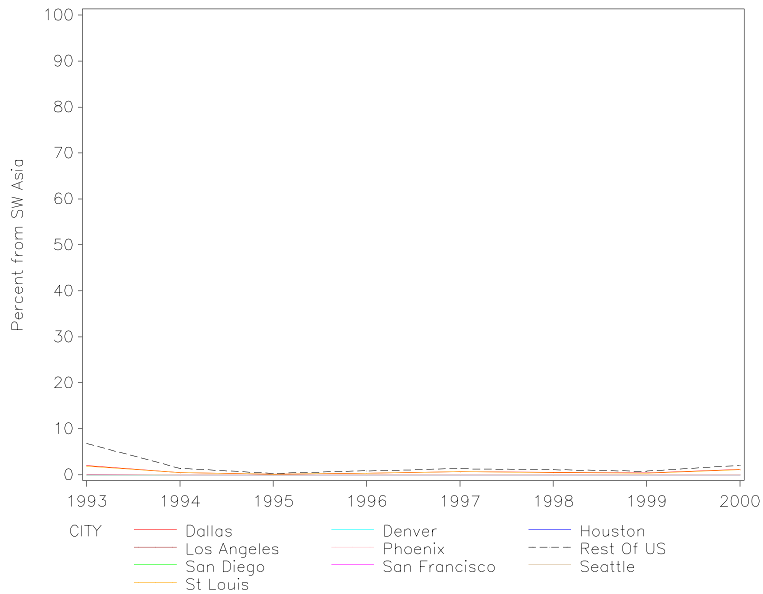


Figure B12: Proportion of Heroin from South West Asia: Western Pattern and Rest of U.S.

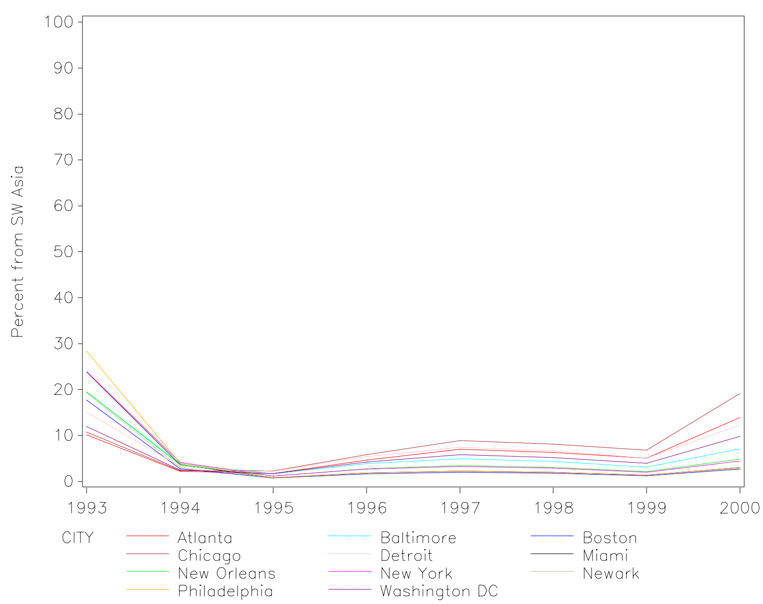


Figure B13: Proportion of Heroin from South West Asia: Eastern Pattern

Appendix C – Import Area Flow Calculations

Since the U.S. regional distribution of seizures in the HSP is not consistent with the U.S. regional distribution of seizures in the FDSS, we cannot simply take the source area distribution of all HSP seizure records and apply that to national seizure totals to arrive at national source area distribution estimates. What follows is a description of how we account for this lack of representativeness in the HSP data.

We begin by tabulating import seizures (per the FDSS) by U.S. Region.

Table C1
CY 2000 - Import Seizures (amounts in export quality kilograms)

U.S. Region	Kgs. Seized
CaliforniaPlus	126.60
TexasPlus	221.81
Northeast	440.97
Southeast	395.94
Other	51.63
TOTAL	1236.95

We then turn to the HSP data to determine the source area distribution of seizures for each U.S. region. This is a simple calculation obtained by tabulating heroin import seizures in the HSP for each import region, partitioning them according to their signature, and calculating the percent of seizures in each import region that are from each source area.

Table C2
CY 2000 - Source Area Distribution of Import Seizures in each U.S. Region

	MEXICO	SOUTH A	SE ASIA	SW ASIA	TOTAL
CaliforniaPlus	69%	11%	0%	21%	100%
TexasPlus	71%	29%	0%	0%	100%
Northeast	0%	39%	18%	43%	100%
Southeast	0%	100%	0%	0%	100%
Other	0%	37%	63%	0%	100%

To identify the national distribution of heroin seizures by source area, we multiply the total amount of heroin seized in each U.S. area (referenced in Table C1) by the source country signature distributions for that area, as calculated in Table C2. We then sum the resulting seizure amounts by source area. The sums for each source area are divided by the national seizure amount to arrive at each source area's share of national import seizures (the last row in Table C3 below).

Table C3
CY 2000 - Source Area Distribution of Import Seizures (amounts in export quality kilograms)

	MEXICO	SE ASIA	SOUTH A	SW ASIA	TOTAL	National %
CaliforniaPlus	87.22	0.00	13.34	26.04	126.60	10.24%
Northeast	0.00	81.22	170.70	189.06	440.97	35.65%
Other	0.00	32.55	19.07	0.00	51.63	4.17%
Southeast	0.00	0.00	395.40	0.54	395.94	32.01%
TexasPlus	158.28	0.00	63.53	0.00	221.81	17.93%
TOTAL	245.50	113.77	662.04	215.63	1236.95	100.00%
National %	19.85%	9.20%	53.52%	17.43%	100.00%	

We also use the data in Table C3 to determine how source area import seizures are distributed among the various import regions. This is done by calculating each cell's percentage of the column total. The results of these calculations are shown in Table C4. Since we are assuming that seizures are representative of the flow in the specific import areas, these figures also represent the proportion of each source country's supply that is shipped through these U.S. areas.

Table C4
CY 2000 - Import Region Distribution of Heroin Seizures for Each Source Area

	MEXICO	SE ASIA	SOUTH A	SW ASIA
CaliforniaPlus	35.53%	0.00%	2.02%	12.08%
Northeast	0.00%	71.39%	25.78%	87.67%
Other	0.00%	28.61%	2.88%	0.00%
Southeast	0.00%	0.00%	59.72%	0.25%
TexasPlus	64.47%	0.00%	9.60%	0.00%
TOTAL	100.00%	100.00%	100.00%	100.00%

Multiplying each source area's consumption-based availability estimate by the above distribution proportions, we arrive at estimates of the amount of heroin that is flowing from each source region into each U.S. importation area.

Table C5
CY 2000 - Estimated amount of heroin imported into each area (in pure kilograms)

	MEXICO	SE ASIA	SOUTH A	SW ASIA	TOTAL	
Availability (kg)	3,540.00	310.00	9,580.00	930.00	14,360.00	[derived availability estimates]
CaliforniaPlus	1,257.69	0.00	193.07	112.30	1,563.06	
Northeast	0.00	221.30	2,470.07	815.37	3,506.74	
Other	0.00	88.70	275.95	0.00	364.66	
Southeast	0.00	0.00	5,721.64	2.33	5,723.96	
TexasPlus	2,282.31	0.00	919.27	0.00	3,201.58	
TOTAL	3,540.00	310.00	9,580.00	930.00	14,360.00	