Appendix A

ESTIMATING AVERAGE LIFETIME COCAINE CONSUMPTION

The principal performance metric in this research is the *weight* (e.g., in kilograms) of cocaine consumption averted per million program dollars. The prevention literature allows us to estimate reductions and delays in the *number* of initiations into cocaine use and, hence, the *number* of cocaine use careers. To bridge the weight and number, in this appendix we estimate the average weight of cocaine consumed over the course of one typical career of cocaine use. There is no one best way of estimating average lifetime cocaine consumption, so a variety of different methods are employed, yielding a range of estimates.

HISTORICAL CONSUMPTION DIVIDED BY NUMBER OF USERS

Conceptually the correct way to estimate average lifetime consumption would be to follow a large number of users throughout their entire history of use, sum their total consumption, and divide by the number of users. Something like this can be done by dividing Rydell and Everingham's (1994) estimates of national cocaine consumption from 1962 through the end of 1991 (4,116.3 metric tons) by their estimate of initiation over the same period (24.34 million). The result is 169.1 grams.

However, the lifetime consumption of all people who initiated between 1962 and 1991 is equal to the total quantity of cocaine consumed in those years only after making two adjustments to the latter

number. One must subtract the consumption between 1962 and 1991 of people who initiated before 1962 and add the consumption after 1991 of people who had initiated by then and who had not yet quit. In other words, if we let X = average lifetime consumption:

$$X = \frac{\text{Consumption Between 1962 and 1991} - \text{Adjustment \#1} + \text{Adjustment \#2}}{\text{Number of People Who Initiated Between 1962 and 1991}}.$$

The first adjustment is easy to make if we assume that everyone who was already using cocaine in 1962 completes their lifetime consumption by 1991. Under that assumption, every individual who was a light user at the beginning of 1962 consumes X grams between 1962 and 1991. (Because the Everingham and Rydell demand model is Markovian, expected lifetime consumption and the expected subsequent lifetime consumption of a current light user are the same.)

As we shall soon see, the subsequent lifetime consumption of a heavy user is 5.56 times that of a light user. Hence, if L_{1962} and H_{1962} represent the numbers of light and heavy users at the beginning of 1962, then the quantity in Adjustment #1 is $(L_{1962} + 5.56H_{1962})X$.[1]

By parallel reasoning, if L_{1992} and H_{1992} represent the numbers of light and heavy users at the beginning of 1992, then the quantity in Adjustment #2 is $(L_{1992} + 5.56H_{1992})X$. Inserting these expressions into the equation above and using the notation,

C_t = consumption in year t and

I_t = initiation in year t

yields

$$X = \frac{\sum_{t=1962}^{1991} C_t}{\sum_{t=1962}^{1991} I_t + \left(L_{1962} + 5.56H_{1962}\right) - \left(L_{1992} + 5.56H_{1992}\right)}.$$

[1]Because the consumption of light and heavy users differs so greatly, it will be useful to differentiate them, as Rydell and Everingham did.

Everingham and Rydell (1994) estimate that $L_{1962} = 0.33$, $H_{1962} = 0$, $L_{1992} = 5.6$, $H_{1992} = 1.72$,

$$\sum_{t=1962}^{1991} C_t = 4{,}116.3 \text{ metric tons},$$

and

$$\sum_{t=1962}^{1991} I_t = 24.34 \text{ metric tons}$$

—all in millions—and, thus, that X is 433.0 grams.

Parallel reasoning can be applied to numbers of years of light and heavy use. However, before doing so, it will be useful to work up expressions for the needed variables by trying another approach to estimating lifetime cocaine consumption.

CONSUMPTION PROJECTED THROUGH A MODEL OVER AN INFINITE HORIZON

Everingham and Rydell (1994) posit a Markov model of cocaine use, from which we can calculate the expected number of years of light and heavy use over an individual cocaine consumer's career. Using the notation

$j(S)$ = expected number of future years of light use for someone who is now in state S,

$h(S)$ = expected number of future years of heavy use for someone who is now in state S,

where $S \in \{L, H\}$ is the state indicator, with L and H indicating light and heavy use, respectively, and

a = annual rate of flow of light users into nonuse,

b = annual rate of flow of light users into heavy use,

f = annual rate of flow of heavy users into light use, and

g = annual rate of flow of heavy users into nonuse,

we can write the following equations:

$$\begin{aligned} j(L) &= 1 + (1 - a - b)j(L) + b\, j(H) \\ j(H) &= (1 - f - g)j(H) + f\, j(L) \\ h(L) &= (1 - a - b)h(L) + b\, h(H) \\ h(H) &= 1 + (1 - f - g)\, h(H) + f\, h(L). \end{aligned}$$

If we solve these algebraically using the parameter values from Everingham and Rydell of $a = 0.15$, $b = 0.024$, $f = 0.04$, and $g = 0.02$, we get

$$\begin{aligned} j(L) &= (f + g)/(af + ag + bg) = 6.329 \\ j(H) &= f/(af + ag + bg) = 4.219 \\ h(L) &= b/(af + ag + bg) = 2.532 \\ h(H) &= (a + b)/(af + ag + bg) = 18.354. \end{aligned}$$

Since initiates are assumed to start as light users, this means that the expected career involves 6.329 years of light use and 2.532 years of heavy use. Consumption per year under base rate conditions is estimated to be 16.42 grams and 118.93 grams for light and heavy users, respectively (Everingham and Rydell, 1994), implying an average career of cocaine use involves 405.0 grams of cocaine consumption.

A side calculation allows us to estimate the ratio of future consumption for a current heavy user to the future consumption for a current light user as

$$(16.42j(H) + 118.93\, h(H)) \div (16.42j(L) + 118.93 h(L)) = 5.56.$$

CONSUMPTION PROJECTED THROUGH A MODEL OVER A FINITE HORIZON

The previous estimate is too high because it extrapolates the Markov model out into the infinite future. In reality, as users get older, the Markov model breaks down. Past work (such as Rydell and Everingham, 1994 and Caulkins et al., 1997) used a 15-year evaluation horizon. For treatment programs, that meant extrapolating the Markov model 15 years beyond the age at entrance into the program—which

occurred only after commencement of heavy use. For enforcement programs, it was 15 years whether use was initially light or heavy, but since the majority of use was attributable to heavy users, the implicit assumption was not very different from that for treatment. In the case of prevention, benefits start at the age of cocaine initiation. We know the latter is 21.5 years, while the average of entrance into treatment is 32 years. Thus, extrapolating to an age 15 years beyond entrance into treatment is similar to extrapolating to an age that is 15 + 32 – 21.6 = 25.4 years beyond initiation. If we numerically project numbers of light and heavy use years over a 25- or 26-year horizon and linearly interpolate between the two to get an estimate for 25.4 years, we get the figures shown in Table A.1, including an estimate of average lifetime cocaine consumption of 291.93 grams.

We need to keep in mind that all the calculations based on the Everingham and Rydell model have converted years of light and heavy use to grams consumed using the average consumption rates in 1992. Those rates were influenced by the price of cocaine at the time. Prices had been much higher before the 1980s. Since consumption responds to price, cocaine consumption careers that included those earlier years most likely involved less consumption, on average, than these calculations suggest.

However, it is appropriate to use the figures we do—16.42 and 118.93 grams per year of light and heavy use—for two reasons. First, we are most interested in estimating the quantity of cocaine that would be consumed by someone starting to use it today. Is it appropriate to assume that the current situation will prevail? We certainly do not know what cocaine prices will be in the next few decades, so price effects cannot be factored in directly. But, particularly given the gen-

Table A.1

Finite-Horizon Lifetime Consumption Estimates from the Markov Model

Time Horizon (years)	Years of Light Use	Years of Heavy Use	Lifetime Consumption (grams)
25	5.99	1.61	289.54
26	6.01	1.65	295.52
25.4	6.00	1.63	291.93

eral stability of prices in the 1990s, projecting a future like the present is not altogether unreasonable. Second, a central goal of this research is to compare prevention's effectiveness to that of other cocaine control programs, and those programs were evaluated as they operated in 1992. Thus, we should base our estimates of prevention's effectiveness on these same assumed rates of consumption per year.

ADJUSTING THE HISTORICAL APPROACH FOR YEARS OF USE

Let's return to the historical approach. We adjusted it for quantities consumed before 1962 and after 1991, expressed in grams. Now, using the equations from the Markov model, we will adjust it for quantities consumed outside the period, expressed in years of use. We begin with

$$\sum_{t=1962}^{1991} I_t j(L) + (L_{1962} - L_{1992}) j(L) + (H_{1962} - H_{1992}) j(H) = \sum_{t=1962}^{1991} L_t$$

and

$$\sum_{t=1962}^{1991} I_t h(L) + (L_{1962} - L_{1992}) h(L) + (H_{1962} - H_{1992}) h(H) = \sum_{t=1962}^{1991} H_t.$$

The ratios of *j(L)* to *j(H)* and *h(L)* to *h(H)* are $(f + g)/f = 1.5$ and $b/(a + b) = 0.1379$, respectively, from the infinite horizon equations above. Everingham and Rydell (1994) estimate that

$$\sum_{t=1962}^{1991} L_t = 119.73$$

and

$$\sum_{t=1962}^{1991} H_t = 19.25,$$

yielding estimates that $j(L)$ = 6.68, $h(L)$ = 2.92, and lifetime cocaine consumption averages 456.9 grams.

STEADY-STATE ESTIMATE

An alternative approach is more empirical. We could observe both consumption and initiation in one year. If the cocaine system were in a steady state, then dividing the first of those two numbers by the second would give the expected lifetime consumption. Obviously the cocaine system is not in a steady state; indeed, drug epidemics are called epidemics in part because they are dynamic. Nevertheless, this calculation is easy to make and may offer circumstantial evidence about average lifetime consumption.

Rydell and Everingham (1994) estimate that in 1992, U.S. national cocaine consumption was 291 metric tons. Johnson et al. (1996, p. 36) estimate that 547,000 people started using cocaine in 1992. So the steady-state assumption would yield an estimate of 532.0 grams consumed over a lifetime of use.

SUMMARY

Table A.2 summarizes the estimates derived above. Considering the strengths and limitations of these approaches, we set our low, mid-range, and high estimates as follows. Given that 169 grams is almost certainly too low but that we have a 292-gram estimate that we think is unbiased, we set a low plausible estimate at 225 grams. We have three estimates falling into a fairly narrow band from 405 to 457 grams, so those must carry some weight in deciding on a mid-range "best" estimate. Thus, we set the mid-range estimate at 350 grams, roughly halfway between the no-known-bias 292-gram figure and the cluster of three estimates over 400 grams. Because the highest figure of 532 grams is methodologically the weakest, we set the high estimate just above the cluster of three at 475 grams.

Table A.2

Alternative Estimates of Average Lifetime Cocaine Consumption

Method	Estimate of Average Lifetime Consumption (in grams)
Consumption over historical period, based on grams, unadjusted	169
Consumption over historical period, based on grams, adjusted for use outside period	433
Consumption over historical period, based on years of use, adjusted for use outside period	457
Infinite-horizon Everingham & Rydell model	405
Finite-horizon Everingham & Rydell model	292
Steady-state assumption	532