2. Results: The Price and Expected Purity of Specific Drugs

Powder Cocaine

Four quantity levels are identified and examined for powder cocaine:

- 0.1 to 2.0 grams, unadjusted for purity (Q1)
- 2.0 to 10.0 grams, unadjusted for purity (Q2)
- 10.0 to 50.0 grams, unadjusted for purity (Q3)
- More than 50.0 grams, unadjusted for purity (Q4)

Estimated annual cocaine price series for each of these levels, evaluated at the median amount for that quantity level, are shown in Figure 1. For example, the median quantity purchased in Q2 observations across all years was 5 grams, so a price of $100 per expected pure gram at this quantity level would indicate that $500 was paid for 5 expected pure grams, and a smaller amount would have been paid for 5 grams of what was expected to be less than 100 percent pure cocaine.

These price series share many features familiar from earlier reports: very sharp (roughly 70 percent) declines during the 1980s through 1989 at all quantity levels, a pronounced (22 to 35 percent) one-year increase from 1989 to 1990, and gradual declines during the 1990s so that prices at the end of the 1990s were 30 to 40percent below those in 1989. With the additional data for 2000 forward, the series show an apparent price jump between 1999 and 2000 that was sustained until 2001, at least at the lowest quantity level. Prices continued to decline uniformly, however, from 2001 to 2003, reaching all-time lows roughly 12 to 21percent below those in 1999. Cumulatively, powder cocaine prices have declined by roughly 80 percent since 1981, with the average price of one expected pure gram of cocaine purchased at Q1 (i.e., 0.1 to 2.0 bulk grams) costing approximately $107 in 2003.

Figure 2 provides information on the interquartile range of prices for each of these powder cocaine series from 1981 through 2003. It shows that the decline observed in average prices throughout the 1980s substantially exceeds the variability in prices observed at any other point in time. Hence, the decline that occurred between 1981 and 1989 is likely to be real, not a statistical artifact. The increase in average prices observed in 1990 is accompanied by a substantial jump in the prices observed within the interquartile range for all quantity levels. These simultaneous shifts upward for all quantity levels stand in sharp contrast to the prevailing downward trend in prices prior to this period. That trend over the 1990s appears to be substantial relative to the variability in prices in any given year, particularly prices in 1990 or 1991 are compared to those in 2003. This can be seen more clearly in Figure 3.

The interquartile ranges for prices tend to be broader at lower quantity levels. Thus, there is less variability in STRIDE observations drawn from higher quantity levels, such as Q3 and Q4, than at lower levels. This could be because there is actually less price dispersion at the higher levels or it may reflect better knowledge on the part of law enforcement of reasonable transaction costs at higher quantity levels.

A striking characteristic of the four powder cocaine price series is that they are very highly correlated, certainly in the long run, reflecting the common price variation between 1981 and

1993 (minimum correlation of 0.99) but relatively greater price stability (correlations of 0.71 to 0.91) even over the past ten years. In particular, prices at the lowest quantity level (Q1) are consistently 1.5 to 2.1 times those at the next higher level (Q2), 1.9 to 3.1 times the Q3 level prices, and 2.7 to 3.9 times those at the Q4 level.

The all-time lows in prices (which, like prices throughout this report, are adjusted for expected purity and inflation) are not accompanied by all-time highs in expected purity, as can be seen by comparing the average predicted prices in Figure 1 to the average predicted purities in Figure 4. Powder cocaine purity peaked in 1987–1988. Expected purity at Q1 (the lowest quantity level) is near all-time highs, and at Q2, although well below peak levels, is still higher than it has been in the past five years. However, average expected purity at the highest quantity levels (Q3 and Q4) has not fully recovered from its extended slide since the late 1980s and appears to be below the expected purity seen at the lowest quantity level for the past four years. Still, Figure 5, which includes the interquartile range of expected purities for each year and each quantity level, shows that these differences in trend lines for average expected purity are generally not large compared with the variability at any one time, as indicated by the interquartile range. The one notable exception is the difference in expected purity observed between Q4 and Q1 and Q2 during the mid-1980s, which suggests that the expected purity of cocaine at lower quantity levels rose more slowly than did that at the highest quantity level in the first part of the period and then rose more quickly than the highest quantity level in the mid-1980s. Indeed, considering the width of the interquartile ranges at the lowest quantity level (Figure 6), expected purity at this quantity level appears to have been fairly stable since the increases that occurred prior to 1987, except for a decline around the 1990 price spike and perhaps around the 2001 price increase as well. Figure 7 suggests that the Q4 level has experienced less stability and a greater decline since the late 1980s, which is why the expected purities converge across these levels.

Unlike what was seen for expected purity-adjusted prices, the spread in the distribution of predicted purities does not diminish as quantity level increases. Even at the higher quantity levels, considerable variability remains in expected purities, making it important not to over interpret apparent trends in simple averages.

Figures 8 and 9 provide city-specific time trends in average price and expected purity, respectively, for five regionally dispersed cities for which STRIDE contains a large number of powder cocaine observations in the lowest quantity level.[13] Ninety-five percent confidence intervals for the city-specific standardized prices are available in Appendix D of the accompanying technical report. Figure 8 shows that the downward trend in powder cocaine prices during the 1980s occurred systematically across a sample of cities from different regions. Similarly, the upward trend in average expected purity during the mid-1980s followed by a leveling off appears fairly robust. This consistency in trends across cities suggests that the trends in the national aggregate series described above can reasonably be thought of as national, not as an artifact produced by variation over time in the number of observations from each city (a concern expressed by the NRC). Although the level of prices appears to differ substantially across cities, the confidence intervals around the price estimates are fairly large so these

[13] This report provides city-specific price information for only a small number of cities that are consistently observed in the data over most of the time period examined. The observed patterns and trends in these data can be viewed as fairly reliable.

differences are not statistically significant. Some of the intercity differences in the level of purity of cocaine, however, are statistically significant for particular years and cities.

Crack Cocaine

Crack cocaine price and expected purity series begin in 1986; in earlier years, insufficient data were available for estimation. Recall, as noted in the introduction, that technically the series labeled here as *crack* is derived from all cocaine base observations in STRIDE, the majority but not necessarily all of which are literally crack. Three quantity levels are identified and examined for crack:

- 0.1 to 1.0 grams, unadjusted for purity (Q1)
- 1.0 to 15.0 grams, unadjusted for purity (Q2)
- More than 15.0 grams, unadjusted for purity (Q3).

It is important to note that quantity levels Q1, Q2, and Q3 for crack differ from those levels for powder cocaine. For example, Q1 for powder cocaine includes observations up to 2.0 grams, a larger range than is specified for crack. Because drugs are sold with substantial quantity discounts, this depresses the average prices for powder at the Q1 level relative to what would be recorded if Q1 for powder cocaine matched the range identified for crack. Hence, direct comparisons should not be made of the *levels* of prices for crack and powder cocaine.

The estimated annual average price of crack cocaine for each of the three quantity levels is shown in Figure 10. The crack series display many of the same prominent features as the powder cocaine series: sharp price declines during the 1980s through 1989, an even more pronounced (30 to 45 percent) one-year increase from 1989 to 1990, and gradual modest declines at levels Q2 and Q3 during the 1990s, with prices at the end of the 1990s about 10 percent below those in 1989. There are some differences, however. Crack prices rose from 1998 to 1999 and from 1999 to 2000, whereas powder cocaine prices did not begin to increase until 2000. All three crack series increased from 1996 to 1997, whereas for powder cocaine, two increased and two decreased. Notably, prices at the lowest quantity level (Q1) did not trend downward during the 1990s. As a result, while Q2 and Q3 crack prices reached all-time lows in 2003, Q1 crack prices did not.

The variability surrounding these estimates of average price per expected pure gram of crack is illustrated by the spread within the interquartile range of estimates shown in Figure 11. The decline in the reported average price of crack during the 1980s was likely to reflect a real decline, particularly at the higher two quantity levels. Further, the increases in average price in 1990 and 1999–2000 were accompanied by rather large shifts in the interquartile distribution of prices for those years, suggesting that these spikes could be statistically meaningful particularly at the lowest quantity level (Q1). In general, the results presented in Figure 11 reinforce the conclusion that the average price of crack cocaine has remained fairly stable since the beginning of the 1990s, particularly at the two highest quantity levels.

As was the case with powder cocaine, there is a fairly stable ratio of crack prices at different quantity levels. Crack prices at Q1 are 1.8 to 2.6 times those at Q2, which in turn are consistently 1.4 to 1.7 times those at Q3. The ratio of Q1 prices to those at Q2 and Q3 has

increased somewhat over time, since Q1 crack prices did not fall during the 1990s, but the ratio of Q2 and Q3 prices is strikingly stable.

The average expected purity of crack—although increasing since 2000—is still, like that of powder cocaine, well below the record levels seen in the late 1980s (see Figure 12). However, as shown in Figure 13, there is considerable variability in these estimated purities at all quantity levels. This can be seen more readily in Figure 14, which shows the interquartile range of estimates for the highest quantity level (Q3), revealing a clear decline in expected purity during the 1990s before the recent rise. This variability during the 1990s is particularly surprising in light of the relative stability in expected purity-adjusted prices for this quantity level during the same period. Another interesting finding from Figure 13 is the extensive overlap in interquartile ranges of expected purity between Q1 and Q2. Given that there is substantial overlap in the interquartile range of these two series, one should not put too much credence in the finding that the average expected purity is lower at the second quantity level than it is at the first; these differences could reflect sampling variability or spatial-aggregation issues.

Geographic differences in crack cocaine market prices for specific cities in the STRIDE dataset can be seen clearly in Figure 15. For example, the downward trend in prices during the mid-1980s occurred to very different degrees in different markets. In Washington, DC, the price of one expected pure gram of crack cocaine dropped by 32 percent between 1986 and 1987, while it went up by 67 percent in New York City. And while New York, Chicago, and, to a lesser degree, Washington DC experienced increases in the price of crack between 1999 and 2000, the price in San Diego appeared to increase a year earlier and fall back in 2000. More generally, the average correlation among Q1-level crack prices in Atlanta, Chicago, New York, San Diego, and Washington, DC, was only 0.15, while that for powder cocaine was 0.65 over the same years and cities. Thus, except for the broad decline in the 1980s, the national average trends for crack are truly nothing more than an average of sometimes divergent city-specific trends; many cities experienced year-to-year fluctuations that differed from those shown in Figure 10. Similar idiosyncratic differences in the expected purity of crack cocaine can be seen in particular years for each of these cities (see Figure 16); however, the general trend across all the cities appears to be fairly robust: All show a decline in expected purity between 1988 and 1999.

Comparison of Powder Cocaine and Crack Cocaine Price Series

As mentioned above, the powder cocaine and crack cocaine price series share some dominant features: sharp price declines through 1989; spikes in 1990 and 2000, as well as a smaller bump in 1995; and substantial declines from 2000 to 2003. (Alone among the seven series, crack prices at the lowest quantity level increased between 2002 and 2003.) Hence, since the first year of the crack series (1986), the various crack and powder cocaine series generally display a fairly high correlation. The average correlation coefficient across all these series is 0.93, with the lowest correlation coefficient, 0.87, occurring for the lowest quantity levels (Q1).[14] However, this apparent correlation stems in part from the shared dramatic changes between 1986 and 1991 and common trends in prices at higher quantity levels. Over the past ten years, the Q1 crack series diverged from the other six cocaine-related price series; its correlation with the Q1 powder cocaine series was only 0.29 over that time. That is, retail powder cocaine series are more highly correlated with wholesale crack series than with retail crack series. These differences in trends

[14] Average correlations were calculated as pair wise correlations across both substances and all quantity levels.

across drug forms support the National Research Council's recommendation to disaggregate drug products by form, when possible.

The finding that crack prices are typically higher than powder cocaine prices at the lowest quantity level appears to contradict previous work by Caulkins (1997), which showed that, on average, retail crack and powder cocaine were equally expensive.[15] However, the lowest quantity levels for crack and powder cocaine are not defined identically in this report, as was explained previously, and they are evaluated at different quantities. Thus the apparent difference in prices may not be real, and further analysis is needed before any conclusions can be drawn.

Heroin

As noted above, the heroin price and expected purity series are generated using observations identified in STRIDE as either *heroin base* or *heroin hydrochloride*. Three quantity levels are identified and examined in this report:

- 0.1 to1.0 gram, unadjusted for purity (Q1)
- 1.0 to 10.0 grams, unadjusted for purity (Q2)
- More than 10.0 grams, unadjusted for purity (Q3).

Heroin price series for each of these quantity levels are shown in Figure 17. The trends in these series share many features with the powder cocaine price series shown in Figure 1, including very large (roughly 55 percent) price declines during the 1980s through 1989, a pronounced (30 to 50 percent) increase from 1989 to 1990 for the two larger quantity levels, and further declines during the 1990s, with expected-purity-adjusted prices at or near all-time lows in 2003. There are some important differences between the heroin and powder cocaine series, however. For example, the 1989–1990 price spike did not occur at the Q1 level for heroin, while the spike for the Q2 level for heroin was much more pronounced than the Q2 spike for powder cocaine, and it lasted two years. Further, there was no spike or other disruption in the heroin price series in 1995 at any quantity level and at most perhaps a slight leveling in prices in 2000. As a result, heroin prices at the end of the 1990s were 55 to 65 percent lower than they were in 1989; the corresponding decline for powder cocaine was 30 to 40 percent. Heroin prices have declined another 10 to 20 percent since the late 1990s, as have powder cocaine prices.

Heroin prices reached all-time lows in 2002 and stabilized at roughly those levels in 2003. Cumulatively, heroin prices have fallen roughly 85 percent since the beginning of the price series, so prices in 2002–2003 were only about one-sixth of what they were in 1981. These tremendous price declines occurred at all quantity levels. Indeed, the three heroin price series are highly correlated not only over the full range of years but even for just on the past ten years. During the past ten years, heroin prices at the Q1 level were consistently 1.1 to 1.6 times those at the Q2 level, and prices at that level were in turn 1.3 to 2.1 times higher than those at the Q3 level (see Figure 18).

The interquartile range of predicted prices is shown in Figure 19 for each year ; the ranges suggest that the decline in average quality-adjusted price over the 22-year period exceeds the within-period interquartile variability for most of the quantity levels. However, there appears to

[15] Caulkins J. 1997. "Is Crack Cheaper than (Powder) Cocaine?" *Addiction* 92(11): 1437-1443.

be significant overlap in the interquartile ranges across quantity levels for most time periods throughout the full period, suggesting that differences in prices across specific quantity levels may not be meaningful. Finally, as was the case with powder and crack cocaine, the variability in predicted prices at the Q1 level is substantially greater than that at the higher quantity levels, suggesting that there may be less variability in prices at higher quantity levels or that enforcement agents have better knowledge about these prices.

The average expected purity of heroin is shown in Figure 20. Unlike powder cocaine, the expected purity of heroin generally rose throughout the period when prices were falling. Expected purity levels today, however, are not at their all-time highs; they appeared to peak in the mid- to late-1990s, depending on quantity level. The rise in average expected purity from 1981 through the early 1990s is very pronounced, even when one considers the uncertainty in the point estimates (see Figure 21). The variability in expected purity between 1992 and 2000, however, may reflect noise caused by differences in samples over time rather than true variability in the average expected purity, perhaps with the exception of 1996. Since 2000, there has been a modest shift downward in the interquartile range of predicted purity at all levels.

City-specific heroin price series for the lowest quantity level (Q1) are shown in Figure 22. There are pronounced differences in the level of average prices across cities, differences that are statistically significant in particular years.[16] Those differences became substantially smaller during the 1990s, so that by 2003, the differences in price per expected pure gram across cities were relatively small. Large differences in average expected purities across cities remain, however, as can be seen in Figure 23. New York City has a much higher average expected purity for heroin than do Washington DC and Chicago, which have the lowest purities, although all three cities show a general rise in expected purity since the early and mid-1980s. The trends in expected purity differ across cities since the mid-1990s, however, with some cities, specifically New York and Washington DC, experiencing a leveling off in average expected purity, while others (Atlanta, Chicago and San Diego) had moderate declines. Thus, as shown in Figures 22 and 23, differences exist across geographic markets for heroin, and care should be taken in interpreting trends in simple averages in the national indices. Spurious trends can be generated by the inclusion or exclusion of observations from particular cities in a given year.

d-Methamphetamine

As noted earlier, only the d-forms of methamphetamine are considered in this report . The three quantity levels identified and examined for d-methamphetamine are as follows:

- 0.1 to 10.0 grams, unadjusted for purity (Q1)
- 10.0 to 100.0 grams, unadjusted for purity (Q2)
- More than 100.0 grams, unadjusted for purity (Q3)

Price and expected purity trends for cocaine, crack, and heroin are relatively easy to describe: long-term trends are interrupted by occasional modest price spikes, and trends at all quantity levels are generally highly correlated. Series for d-methamphetamine prices are far more irregular in two respects, as shown in Figure 24. First, in the 1980s, trends are not concordant

[16] See Appendix D in the accompanying technical report for tables that present the 95 percent confidence intervals for these estimates.

across quantity levels. For example, Q1 prices through 1984 were declining, while Q2 prices were increasing. Second, although the price series for the three quantity levels are concordant with each other after 1988, they are still highly variable, with pronounced spikes in 1990–1991, 1995 perhaps extending into 1996, and in 1998. The distinct trends at each quantity level exceed the associated interquartile ranges of predicted values for each year, as shown in Figure 25. Although there is some minor overlap between the interquartile ranges for the two lowest quantity levels, the markets remain fairly distinct, as do the pattern in prices prior to 1988.

Trends in the average expected purity of d-methamphetamine display the same irregularities as those for expected-purity-adjusted price, as shown in Figure 26. Each quantity level exhibits a different pattern between 1981 and 1988, then after 1988, the trends move concordantly, with troughs in 1990–1991, 1995, and 1998 across all quantity levels. Unlike expected-purity-adjusted prices for d-methamphetamine, however, the difference in expected purity trends prior to 1988 are modest relative to the great variability within each quantity level, as indicated by the interquartile ranges in Figure 27. Indeed, it is not clear that there is a substantial difference in average expected purity across quantity levels for d-methamphetamine until 1995, at which point the interquartile range of predicted purities for the Q1 and Q3 levels begin to separate. The peak and troughs since 1988 suggested by Figure 26 represent substantial shifts relative to within-period variability, as is more readily apparent in Figures 28 through 30, which show the interquartile range of predicted average purities for each quantity level separately.

There is tremendous volatility in the price and expected purity of d-methamphetamine, with the average expected purity following trends that mirror those observed in the price series for the two lowest quantity levels. Figure 31 shows how expected purity troughs correspond with price spikes in the Q1 level. The estimated correlation coefficient between these two series is –0.82, slightly higher in absolute value than that observed for the Q2 level (estimated correlation of –0.63). Today, d-methamphetamine prices are at or near all-time lows, with current prices approximately 40 percent lower than their average during the 1990s. Average purities have also been rising quite steadily since their trough in 1998 but have not yet reached their 1994 peak levels.

The d-methamphetamine series merit focused follow-up research for at least two reasons. First, unlike cocaine and heroin observations, d-methamphetamine observations are highly concentrated in one region of the country (the Southwest). Indeed, one city (San Diego) accounts for nearly 25 percent of all the d-methamphetamine price observations. (See Figures 32 and 33 for city-specific estimates of expected purity-adjusted price and expected purity, respectively.) Varying numbers of observations made over time in other cities and at different rates at different quantity levels could generate spurious trends and other artifacts, such as the inversions in predicted purities observed across quantity levels.

A second reason for further follow-up research on the d-methamphetamine series is the fact that patterns identified in this report differ sharply from those presented in previous reports. It may be that the methodological changes made in the modeling used for this report, including focusing on only one type of methamphetamine, make it easier to see real trends in the volatile and sparse methamphetamine data. Nonetheless, before attributing substantial meaning to these d-methamphetamine series, their external validity should be explored by examining how well they correlate with trends in methamphetamine-related outcomes obtained from other data sources. For example, the price and expected purity spikes and troughs reported in Figures 24, 26, and 31

appear to overlap with the introduction of methamphetamine precursor chemical regulation introduced in 1989, 1995, and 1997. Precursor regulations are intended to restrict supply, so one would expect to see price spikes and possibly expected purity troughs following these precursor control interventions. Cunningham and Liu (2003) have examined the extent to which hospital admissions for methamphetamine use and/or abuse in the Southwest correlate with the adoption of these laws, and a similar investigation could be performed for methamphetamine prices.[17]

Marijuana

Marijuana trends are in some sense simpler than those of the other drugs, because they pertain only to price. Information on the potency of marijuana observations is not available through STRIDE. Furthermore, the quantity levels identified and examined in this report correspond to those employed in previous reports, allowing for some basic comparison in trends across reports. The three quantity levels examined are:

- 0.1 to10.0 grams, unadjusted for purity (Q1)
- 10.0 to 100.0 grams, unadjusted for purity (Q2)
- More than 100.0 grams, unadjusted for purity (Q3)

The marijuana price trends, shown in Figure 34, are not highly correlated with trends in prices of other drugs over time. While the price of powder, heroin, and, to a lesser extent, crack were falling during the 1980s, the average price of marijuana generally rose, reaching a peak in 1991 for two of the quantity levels. The peak for Q2 occurred in 1993–1994. Prices then declined through 2000, at which time they began a slight upward trend. At quantity levels Q1 and Q2, 2003 marijuana prices were about one-third above their 2000 troughs. This recent price increase leaves current marijuana prices at Q1 and Q2 near their 20-year averages. The prices for Q3, on the other hand, are near all-time lows.

Marijuana prices at different quantity levels range from 0.62 to 0.84 and are thus not as highly correlated over time as those for other drugs, particularly powder cocaine and heroin. Figure 35 shows that there is not a lot of overlap in the distribution of prices across the three quantity levels, suggesting that quantity discounts/price markups across quantity levels exceed variability in prices within a quantity level. However, it would be misleading to speak of ratios of prices between quantity levels for marijuana, as the apparent ratios sometimes seem to depend on the level of prices. For example, roughly speaking, marijuana prices at level Q1 are about three times those at Q3 plus $3/gram, not just three times the Q3 prices. On the other hand, Q2 prices are roughly 1.3 to 2.6 times the Q3 prices.

[17] Cunningham, J., and LM. Liu (2003), "Impacts of federal ephedrine and pseudoephedrine regulations on methamphetamine hospital admissions," *Addiction*, Vol. 98, 2003.