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Abstract:

Drug markets have been targeted for increasingly tough enforcement yet retail prices for cocaine and heroin fell by 70-80%. No research has explained adequately why prices have fallen. This paper explores the possibility that part of the explanation may lie in the failure of drug dealers to respond to risks the way the simplest rational actor models might predict.

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Limited Rationality and the Limit of Supply Reduction

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Bio Sketch:

Dr. Caulkins specializes in systems analysis of social policy problems, with a focus on issues pertaining to drugs, crime, and violence. He received a B.S. and M.S. in Systems Science from Washington University, an S.M. in Electrical Engineering and Computer Science and Ph.D., in Operations Research both from M.I.T.

Dr. MacCoun studies legal decision making and the social control of risky conduct. He received his Ph.D. in Psychology from Michigan State University in 1984. From 1986 - 1993 he was a behavioral scientist at RAND. He is the author (with Peter Reuter) of *Drug War Heresies: Learning from Other Vices, Times, and Places* (Cambridge, 2001).

Running Head: Limited Rationality and Supply Reduction

LimitedRationalityandtheLimitsofSupplyReduction

Abstract

Drugmarketshavebeentargetedforincreasinglytoughenforcementyetretailpricesfor cocaineandheroinfellby70 -80%.Noresearchhasexplainedadequatelywhyprices havefall en.Thispaperexploresthepossibilitythatpartoftheexplanationmaylieinthe failureofdrugdealerstorepondtorisksthe waythesimplestrationalactormodels mightpredict.

The Paradox of Increasing Enforcement and Falling Drug Prices

In recent decades, the prices for cocaine and heroin in the US have fallen despite increasingly stringent enforcement. ¹ The decline during the 1980s was particularly precipitous, but the erosion continued throughout the entire period except for a few brief interruptions (e.g., in late 1989 and mid 1995). ²

Falling prices are problematic because drug use varies inversely with price. Formal estimates of the so-called “elasticity of demand” are usually based on youth and household populations’ self-reports of marijuana and cocaine use. (See Chaloupka & Pacula, 2000, for a review of that literature.) However, the strong negative correlations observed between both cocaine and heroin prices and corresponding emergency room mentions suggest that the relationship is not confined to initiation or to casual users (Caulkins, 2001).

Falling prices in the face of increasing enforcement are puzzling because most of the burden of drug enforcement falls on sellers, ³ and according to elementary economics,

¹ Drug arrests increased from 581,000 in 1980, to 1.1 million in 1990 and 1.5 million in 1999. The number of people incarcerated for drug offenses grew from 42,000 in 1980 to 270,000 in 1990 and 470,000 in 2000. Likewise the federal drug control budget increased from \$1.5B in 1981 to \$9.8B in 1990 and \$18.5B in 2000.

² Caulkins and Reuter (1998) review the evidence on drug prices. The official data from the Office of National Drug Control Policy used to show declines of 60% between 1981 and 1990 and a further 51% decline between 1990 and 1996 for both cocaine and heroin. Those data were revised to show declines of only 42% and 55% for heroin and cocaine, respectively between 1981 and 1990 and declines of 31% and 46% between 1990 and 1996. The data series we have created for other projects are consistent with the first set of numbers, but both sets show sharp declines. Note: The only consistent, detailed price series are generated directly or indirectly from what undercover agents pay for drugs. These transactions may differ in systematic ways from true market prices (see Manski, Pepper, & Petrie, 2001, Chapter 3). It is unlikely, however, that the apparent price collapse is a purely an artifact because anecdotal and ethnographic accounts are consistent with substantial price declines.

³ Many arrests and convictions are for drug possession, but some of those individuals were involved in selling (e.g., those who plea bargain down to a possession charge or who possessed quantities beyond what is suitable for personal use). Straight possession cases are less likely to lead to incarceration. Also the fact that most of those incarcerated for drug offenses participated in selling does not imply that users are not

interventions that restrictors suppress supply typically drive prices up rather than down. Reuter and Kleiman's classic paper on "risks and prices" (1986) presents this argument in detail. The key points are:

- People sell drugs primarily to make money, not for pathological or ideological reasons.
- There are few barriers to entry because (a) few specialized skills and little capital are needed to be a drug supplier and (b) the domestic distribution "industry" is fragmented, so it is not generally in the interest of individual incumbent suppliers or organizations to take costly action to prevent others from entering the market.
- Hence, people enter the drug distribution business until the returns from doing so are biddown to a level comparable to that derived from other activities, i.e. to the opportunity cost of being a dealer.
- The economic return from dealing is the monetary or accounting profit minus the dollar value of non-monetary risks and costs incurred.
- Conventional costs of production are too small to explain or drive prices.

This can be summarized in an equation:

$$\text{Economic return on dealing} = \text{Revenue from selling drugs} - \text{Cost of obtaining the drugs} - \text{Conventional business costs} - \text{Non-monetary costs.} \quad (1)$$

If the return on dealing is governed by the opportunity cost of dealing, then it should be relatively insensitive to changes in enforcement. Since conventional business costs are negligible, this implies that the markup (i.e., the difference between sales revenue and the cost of obtaining drugs) is driven primarily by the non-monetary costs. The sum of the markups from one layer of the distribution chain to the next is what determines the retail price. The risks of enforcement and violence are the dominant non-monetary costs. So, mathematically, one would expect increasing enforcement to drive up non-monetary costs and, hence, prices.

incarcerated; many sellers are also users.

Less formally, the risks and prices framework views enforcement as a sort of tax that drives up the cost of distributing drugs. Since drug dealers are essentially business people, one would expect them to pass those higher costs along to consumers in the form of higher prices. Both before and after any change in the amount of enforcement, drug dealers are reviewed as having made a rational choice. They considered the risks. They considered the rewards (primarily monetary). And they chose the bundle of risks and rewards associated with dealing over whatever the alternative was. Raising the risks makes the bundle look less attractive, so to preserve an equilibrium in which the marginal individual is indifferent between choosing the risky bundle and the less risky default alternative, rewards must rise when risks do.

Conventional Explanations for the Conundrum

The previous section described a paradox. The bulk of this paper examines the possibility that various cognitive failures or failures of judgment might help explain that paradox. Before proceeding it is important to make two observations. First, it is unlikely that there is just one explanation for why cocaine and heroin prices fell when enforcement increased. That is why we say failures in judgment may *help* explain the paradox, not explain it entirely. Second, some of the other explanations do not involve judgmental failure. We review them next. They do not necessarily make this paper moot, however, because these explanations are not typically viewed as being sufficient in themselves to explain all of what happened with prices, even if they are an important part of the overall explanation.

Price Declines Were the Result of Demand Shifts

A common explanation for falling prices is an upward sloping supply curve (the usual case) and declining demand. Superficially this might seem like a relevant explanation because the number of cocaine users (though not necessarily heroin users) has fallen. However, demand is dominated by heavy users, whose numbers grew in the 1980s. Everingham and Rydell (1994) estimate that the weighted sum of the number of light and heavy cocaine users, weighting by their relative propensities to consume, was stable during the 1980s, and Knoll and Zuba's (2002) update shows only very modest

declines during the 1990s. Heroin use is hard to estimate but, if anything, may have been increasing (ONDCP, 1999). So falling demand cannot explain the price declines.

Conversely, the stability in cocaine demand undermines another explanation, namely that growing demand coupled with a downward sloping supply curve is behind the cocaine price declines. Downward sloping supply curves are unusual but can occur when there are few scarce factors of production and there are industry-wide external economies of scale (Samuelson, 1973), which could be the case for drug distribution.

The risks and prices models suggest that prices should be driven by the intensity of enforcement, rather than its total magnitude. That is, it is not the number of people locked up that matters, but the number of people locked up per kilogram sold or per some other measure of market size. Hence, if the market grew faster than enforcement did, this expansion might have diluted enforcement risks -- what Kleiman (1993) refers to as "enforcement swamping." Stable demand undermines this explanation for cocaine. It could possibly have played a role in declining heroin prices, but Reuter (1991) has argued that not only the level but also the intensity of drug enforcement generally increased between 1980 and 1990, even though it might have fallen initially before rising sharply between 1985 and 1990.

Learning-by-Doing and Other Efficiency Gains

Drug prices may have fallen for the same reason computer prices did. The producers may have become more efficient at their craft (cf. Cave & Reuter, 1988; Kleiman, 1989). If so, then even if increasing enforcement kept prices higher than what they otherwise would have been, those increases might have been overwhelmed by a general, secular price collapse. This possibility is being investigated empirically by Bushway and colleagues (personal communications). Note that learning can take place either at the individual level (e.g., if the average seller today has more years of experience than did the average seller in 1980) or collectively (e.g., if even young sellers today can emulate and benefit from innovations developed by others in the past).

Tough Enforcement Might Have Perverse Effects

A more pessimistic explanation is that enforcement was not only swamped by naturally occurring innovation but that increasing enforcement stringency actually prompted that innovation. E.g., Kleiman (1989) suggests that tough marijuana enforcement encouraged smugglers, dealers, and users to substitute into cocaine because it was easier to conceal, and some have made similar suggestions concerning the invention of crack (Friedman, 1989).

Likewise the increasing stringency of enforcement was accompanied by a change in how it was used, who was selling, and where the selling occurred. To caricature, in 1980 cocaine was a rich person's drug purchased through social networks from people whom he moved in the same cultural and economic circles as the users. In 1990, it was a ghetto drug. Even though most users were not poor, most of the small number of heavy users who accounted for the majority of the consumption were. And most selling was done by "professional" sellers who interacted with their customers primarily to transact drugs. Often these sellers were young and had limited opportunities in legitimate labor markets. It is not clear which if any of these trends caused the others, but perhaps increasing enforcement discouraged sellers for whom sanctions were particularly costly.

The customary challenge to arguments for perverse effects is, in effect, that if suppliers were able to cut costs and increase revenue under prohibition and stiffer enforcement, why wouldn't they have done so under prohibition with standard enforcement, to improve profits and beat their competitors? One can generate some plausible answers (cf. Rasmussen and Benson, 1994). E.g., in an atomized market with poor information flows, it can be optimal for every individual to do things in ways that other market participants recognize and understand, so change may not occur until an exogenous force such as enforcement makes the status quo untenable. In general, however, these answers are compelling only for particular contexts and are not likely to explain the overall paradox of price declines.

Diminishing Marginal Effectiveness to Increased Enforcement

There are several reasons why enforcement's marginal effect on prices may diminish with increasing enforcement intensity. By themselves they can only explain why prices didn't increase very much, not why prices actually fell, but they could have played a role in conjunction with other factors.

First, there are what Reuter (1983) calls the "structural consequences of product inequality." The mere fact that drugs are illegal, and that prohibition is not rendered vacuous by a complete absence of enforcement, compels drug suppliers to operate in inefficient ways. For example, they have trouble establishing fixed business locations, advertising, and entering into enforceable contracts.

Second, the consequences of subsequent convictions may be less severe than the consequences of the first in terms of reduced labor market opportunities, social approbation from friends and family, ineligibility for governmental benefits, etc. Likewise, extending sentences may be less cost-effective than imposing shorter sentences (Caulkins, Rydell, Schwabe, and Chiesa, 1997).

Third, it has been hypothesized that the larger the proportion of one's peer group that has been sanctioned, the smaller is the social stigma of receiving that sanction (see Jacobs and Hanneman, 1992; McGraw, 1985; Petersilia, 1990), a phenomenon that might be called "stigma swamping" (following Kleiman's term "enforcement swamping," discussed above).

The Market May Not Have Been in Equilibrium in 1980

The risks and prices argument applies to the long-run equilibrium prices. Economics in general is vague about how long one has to wait for long-run considerations to dominate. The economics of drug markets are no different in that regard. Cocaine as a mass-market phenomenon was relatively new in the US in 1980. Perhaps prices in 1980 were "too high" in the sense of being out of equilibrium, and dealers then were reaping "supernormal" profits. If so, then the mystery is not why prices fell but rather why prices didn't fall faster, and the answer may simply be that information flows very imperfectly in illicit markets so it takes time for the equilibrium to be restored.

These points are relevant and may have contributed to the decline in cocaine and heroin prices. But even in total, they do not present an entirely satisfactory explanation for why enforcement has been so singularly ineffective at driving up prices. So we now introduce another possible explanation, namely that drug enforcement may not deter drug dealers in quite the way the risks and prices paradigm would suggest.

The Limit of Deterrence

The risks and prices paradigm views drug enforcement as working through deterrence. A given intensity of enforcement deters people from selling drugs at prices that provide less than a certain monetary reward. Increasing enforcement risk reduces the range of prices at which drug dealing will be pursued, just as raising the risk of arrest for burglary restricts the number of burglaries that are sufficiently rewarding to commit.

To work, deterrence depends on the object of the enforcement threat behaving with some degree of "rationality" in the sense of consistently choosing courses of action that improve one's well-being relative to the alternatives. As Kleiman (1992) points out, agents of the state including the police do not often literally use force to achieve compliance. Even when a police officer draws a gun and orders a suspect to lie down, the officer is depending on the suspect to choose the benefits of complying with the order over the costs of not complying, namely being shot. If the suspect isn't capable of responding to incentives or making self-interested choices, deterrence will not achieve the desired end.

In essence, the question we raise here is whether rational actor models describe drug dealers' behavior well enough for deterrence to work as is implied by the risks and prices theory. (See MacCoun [1993] for a similar analysis focusing on drug user rather than selling.) We do not for a minute doubt that most if not all drug dealers are capable of responding to incentives. Certainly, we expect most would respond to the threat of a police officer's drawn gun. But the fact that someone responds to incentives is not sufficient evidence to conclude that they are maximizing expected net revenues, utility, or any other objective function. When the price of a good (or activity) goes up, individuals who are consistently maximizing an objective function will not only tend to consume less of the good, they will reduce consumption by a very specific amount as dictated by the

particulars of their objective function and the price change. If they reduce consumption but by a different amount they are responding to incentives but their behavior would not necessarily be well predicted by a rational actor model.

A gap between actual behavior and the predictions of rational actor models could emerge because of “bounded rationality” (Simon, 1957). I.e., the individual might rationally choose not to maximize a given, narrow objective function if the information collection and processing costs are too great. Or the gap could stem from behavior that is not even rational in a bounded sense. As Boyum (1992) observes, the latter is much more plausible for drug sellers than for illicit businesses because drug enterprises are essentially never driven out of business by negative accounting profits. They can operate indefinitely with negative economic profits (return), but still meet payroll if dealers are not receiving full compensation for risk.⁴

A central premise of this article is that for the decision to sell drugs deviations from a naïve notion of rationality are likely to be large, whether because of bounded rationality or even “less rational” behavior. In particular, we hypothesize that they are large enough to play an important role in explaining why increasing enforcement intensity has not had the effect on prices that the risks and prices model would predict. From a modeling perspective, the implication is that the return to dealing need be only weakly related to the return on alternative activities.

We have no way at present to quantify the departures from simpler rational choice on dealer behavior. The goal of this paper is simply to make a case for plausibility by pointing out that the structure of the decision to sell drugs parallels structures that the literature reports lead to perverse behavior, either in controlled experiments or in naturalistic settings.

The case has an *a fortiori* character in the following sense. We strive to show that even modest departures from the classical model of decision-making are sufficient to break the link between drug enforcement and drug prices. To the extent that in reality the

⁴This implies that the zero long-run economic rents assumption underlying the risks and prices paradigm is a stronger assumption when applied to drug enterprises than it is when applied to more typical firms.

decision to sell drugs is even more spontaneous, emotional, and idiosyncratic than we describe, then the conclusion holds with even greater force.

Consistent with this a fortiori character, we consider how the decision to deal might look to someone who tries to look carefully and quantitatively at data concerning the benefits and costs of selling. This discussion is pursued in two parts. First we consider someone who has accurate and representative data concerning the probabilities and consequences of various outcomes. Then we consider reasons why these “inputs” to the decision process may be biased. We also distinguish between three stages of a dealing career: the decision to sell for the first time or first few times, the decision to escalate to regular selling, and the decision to continue selling even after being sanctioned.

The Initial Decision to Sell Drugs

To discuss how human frailties might play a role even with a data-driven attempt to weigh carefully the benefits and costs of selling drugs, it is helpful to use specific numbers. The decision model described is by no means the most sophisticated or inclusive one could devise. We keep it simple for expositional purposes and trust the reader to see that the points made are robust with respect to such elaborations.

Most applications of the risk and prices framework have assumed the decision to deal can be modeled as if it is made on an expected value basis (e.g., Rydell & Everingham, 1994; Caulkin et al., 1997). That is, the marginal dealer is perceived as someone for whom the expected value of the benefits of dealing equals the expected value of the costs, including the opportunity cost of not dealing.

Reuter, MacCoun, and Murphy (1990, pp. 102–105) include an example of this approach. They estimated that someone who sells drugs regularly for a year (at retail, in Washington, DC, in the 1980s) made an average of \$27,000 per year, net of the cost of buying the drugs.⁵ Reuter et al. estimated that such an individual faces a seven percent chance of serious injury, a 1.4% chance of being killed, and a 22% probability of

⁵Regular dealers are defined as those who sold “daily” or several days per week. It excludes those who reported only selling on one day per week.

incarceration with an estimated average time served of 18 months. They hypothesize that these individuals might value a serious injury at \$30,000, a 1% risk of death at \$7,500, and a year in prison at the opportunity cost in terms of lost wages (\$27,000 per year), and thus describe the average return to a year of regular dealing as:

$$\begin{aligned} & \$27,000 - [0.07 * \$30,000 + 0.014 * \$7,500 + 0.22 * 1.5 \text{ years} * \$27,000 / \text{year}] \\ & = \$5,500 \text{ per year} \end{aligned}$$

Assuming regular dealers spend an average of 15.9 hours per week selling, this works out to \$6.65 per hour worked.⁶ Ignoring taxes, that is close to the median hourly wage for legitimate work reported by subjects who had such work (\$7 per hour). This rough equality between the opportunity cost of time spent dealing and the accounting profits net of the monetary value of expected non-dollar costs also held at the industry level in the mid to late 1990s (Caulkins and Reuter, 1998).

Even though these expected value calculations “add up” surprisingly well given the quality of the data, the expected value model may be too simple in important ways. For example, with expected value calculations it makes little difference whether the decision to sell is described in terms of payoffs per week, per month, or per year of selling. Monthly and annual calculations are convenient because various data are available in those time increments, but the choice is almost arbitrary.⁷

However, when the utility function being optimized is more complicated, e.g., because the individual is risk averse, expected monetary value is not a sufficient guide to choice. Non-linearity in utility as a function of payoff can imply that it matters what time frame is contemplated, and for a variety of reasons the decision to sell for the first time is not likely to be perceived as a decision to sell for a year.

⁶ Reuter et al.'s sample included 67 daily sellers and 71 people who sold several times per week, and they use a figure of 4 hours worked per day of selling. We assumed daily sellers sold five times per week, those who sold several times per week sold three times, and, therefore, that a average number of hours worked per week by a regular seller is 15.9.

⁷ Whether it is literally arbitrary depends on what happens when dealers are arrested or killed midway through a planned period of selling.

Some of these reasons are psychological. With respect to probability judgment, people often fail to understand that activities with small per-transaction risks can have very large cumulative risks (Doyle, 1997). With respect to the evaluation of outcomes, people tend to frame choices narrowly and locally rather than broadly and globally (see Kahneman & Tversky, 2000). And it is likely that drug dealing (like other crimes) disproportionately attracts those high in impulsivity and low in self control (Gottfredson & Hirschi, 1990), implying short time horizons.

There are also structural factors that discourage long-term planning. Drug dealers have no employment contracts or union rules prohibiting part-time work or minimum time commitments as in the military. Part-time selling or “moonlighting” as a drug seller is common (Reuter et al., 1990), and the more natural unit of commitment to selling is to carry out one cycle of buying drugs from a supplier, dividing the packages into smaller units, and selling those smaller units to customers. Suppliers generally take a dim view of effort to return merchandise; they offer no money-back guarantees. This makes it costly to abandon dealing mid-cycle, but cycles are short, typically ranging from a few hours to a few days or a week. There is no year-long obligation.

Thus when someone is considering whether to sell drugs for the first time it is probably more realistic to describe the mass decision as deciding whether to execute one drug selling cycle, not deciding whether to commit to sell for a longer period of time, such as a year. Consistent with this argument, Reuter et al. (1990, p. 82) found that relatively few adolescents (in a sample that included quite a few drug dealers) thought they would sell drugs after they left school, even though dealing was actually more prevalent among older cohorts in their neighborhoods.

Decision trees are a useful tool for depicting choices (Raiffa, 1968). Figures 1a and 1b use decision trees to illustrate how the “commit for a year” and “commit for a cycle” perspectives differ. In each case the choice, represented by a box, is to sell drugs or not, and in each case the result of choosing to sell drugs is uncertain, represented by the arrow emanating from the circle, with outcomes ranging from very bad (“death”) to very good (“successfully selling the drugs while incurring no sanction”). The specific payoffs and probabilities differ, however. One is more likely to evade sanction while selling one cycle as opposed to one year (99.3% chance vs. only a 64.1% chance), but the

payoffffordoinngsoismoremodest(\$450vs.\$27,000).

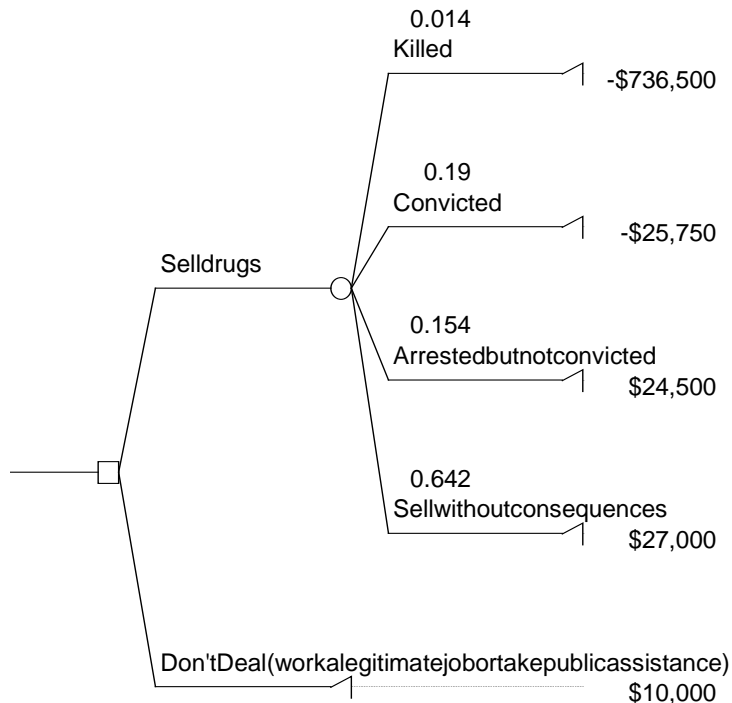


Figure1a:TreeforSellingforOne YearwithZeroPointBeingNotMakingAny Money

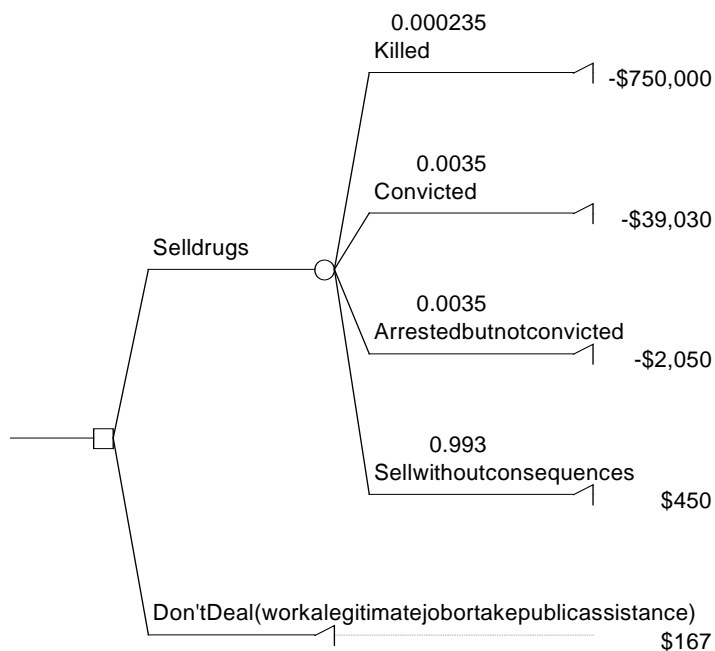


Figure1b:TreeforSellingforOne CyclewithZeroPointBeingNotMaking AnyMoney

The risks, valuations of outcomes, and definition of a cycle are specified in Appendix A. The arrest and conviction probabilities are derived from national data, but are quite similar to the Washington DC-based figures used above. We assume a regular dealer can complete 60 cycles per year. The relationship between the per-cycle and per-year probabilities of adverse outcomes is that implied by a “Bernoulli Process” or “coin toss” model. For example, if the probability of being killed during one cycle is p , we assume the probability of being killed while attempting to execute 60 cycles is $1 - (1 - p)^{60}$. We do not think the Bernoulli model is descriptively accurate, but we want to suppress issues such as discounting, diminishing returns, and skill increasing with experience in order to make the contrast between Figures 1a and 1b be a function only of the time horizon.

We suspect that more people find the “deal” option appealing in Figure 1b, which takes a per-cycle perspective, than prefer the “deal” option in Figure 1a. Agreeing to sell drugs for a year is agreeing to a one-third chance of criminal sanction and a one-in-five chance of being incarcerated. A one-in-three chance of failure is sobering. Recall the warning to freshmen in the past when university retention rates were lower. “Look left. Look right. One of the three of you will not graduate.”

On the other hand, in Figure 1b there is a better than 99% chance of getting away without any adverse consequences. One does not have to be Don Quixote to “give it a go” when the chance of suffering any adverse consequence is less than one in a hundred.

Indeed, some well-known psychological tendencies might lead individuals to choose to deal when looking at Figure 1b even if they would not do so in Figure 1a. In particular, Prospect Theory (Kahneman & Tversky, 1979) suggests that people are risk averse with respect to gains and risk seeking with respect to losses, with gains and losses defined around some reference point (see Appendix B). The reference point can depend on the framing of the decision; in Figures 1a and 1b we describe the reference point as the status quo if he or she neither sells drugs nor works in the alternative employment. If one evaluates the choices in Figures 1a and 1b with utility functions of the form:

$$U(x) = f(x) \text{ for } x > 0$$

$$-f(-x) \text{ for } x < 0$$

for a variety of $f(x)$, selling is preferable when contemplating a single cycle, but not selling is preferred when contemplating a year-long commitment.⁸

Another aspect of prospect theory is that losses are perceived more poignantly than are gains, so there may be a “loss aversion multiplier” ($\lambda > 0$) such that

$$U(x) = f(x) \text{ for } x > 0$$

$$-\lambda f(-x) \text{ for } x < 0.$$

When $\lambda = 2.25$ and $f(x) = x^{0.88}$ (typical values) dealing is not the preferred option from a per cycle or a per year perspective, because losses are weighted so heavily. But if one adopted more optimistic parameters (e.g., profit per cycle were \$650 instead of \$450 or arrest and conviction probabilities were one-third as great) then the “Deal” option becomes preferred under the per cycle perspective but not the per year perspective. Of course if the parameters are optimistic enough (e.g., a profit per cycle of \$1000) then the “Deal” option becomes preferred with either framing. The point, though, is that a tendency to be risk-averse with respect to gains and risk-seeking with respect to losses can make the “Deal” option relatively more appealing with the per cycle perspective.

Another component of prospect theory, however, points in the opposite direction. There is evidence that people weight outcomes not by their probabilities but by a nonlinear function of those probabilities (Appendix B). In particular, “diminishing sensitivity” implies that the impact of a given change in probability diminishes as one moves away from either extreme of certainty (i.e., for outcomes that occur with probability zero or one). Since deciding to deal for even one cycle moves the probability of arrest, incarceration, and death from zero to a positive number and these low probabilities get amplified by the decision weighting function, this phenomenon would tend to discourage people from deciding to deal when considering the “per-cycle” perspective. Indeed, an actor applying prospect theory’s nonlinear decision weighting function would not choose to deal drugs given any of the decision trees we examine in this paper, even in cases where expected value theory predicts drug dealing.

⁸ Functions $f(x)$ for which this is true include $f(x) = \ln(x+1)$, \sqrt{x} , $1 - \exp(-x/R)$ for R less than about 30,000, and x^β for β less than about 0.9.

How this nonlinear decision weighting plays out in practice is complicated by the fact that in reality the “Don’t Deal” option involves some risk. E.g., for a property criminal who has a baseline annual arrest risk of 0.2, then nonlinear decision weighting would tend to *reduce* rather than increase the weight placed on additional risk of arrest. Still such arguments are unlikely to apply to the incremental risk of death. Very few people have a baseline death risk of more than a few percent over their relevant planning horizon. Tversky and Kahneman (1992, p. 303) argue that this nonlinear function “is not well-behaved near the endpoints, and very small probabilities can be either greatly overweighted or neglected altogether.” Perhaps some people are repelled by the “per cycle” framing, e.g. because nonlinear weighting amplifies the death risk, and they never sell, but others view the probabilities of death as essentially zero and have high baseline risks of arrest, so they proceed. Since not everyone decides to sell drugs, we only need to understand why some people might not be deterred, not why none are deterred.

At any rate, the fundamental observation is that unlike expected value calculations, prospect theory suggests that the duration of dealing contemplated (one cycle or one year) can affect whether the “Deal” or “Don’t Deal” option seems more appealing. If the duration is one cycle and the tendency to be risk averse with respect to gains and risk averse with respect to losses swamps the nonlinear weighting effect, then someone who would not agree to sell for a year, might still decide to sell for a cycle.

The Decision to Continue Selling Drugs

The mechanism just described may help explain why some people decide to execute a drug selling cycle once or, by extension, a few times, even if they would not commit initially to selling drugs for an entire year. Yet the phenomenon we seek to explain is not why some people dabble with dealing but why so many become regular dealers in the face of stiff enforcement. Is there something about having sold a moderate number of times that makes people more willing to commit to selling on an ongoing basis? In short, the answer is yes.

A key insight is that most people who execute a few selling cycles incur no sanction for that activity. With the parameters in Figure 1, fewer than four in a hundred people would experience any adverse outcome during their first month of regular selling

(fivecyclesatapaceof60cyclesperyear).Nineoutoften sellforthree monthswithout incident.

Figure1assumedthedecisionmakersassessedgainsandlossesrelativetowhat theyhadbeforedecidingtosell drugs,namelynothing.Oncesomeonehassuccessfully solddrugsforafewcycles,thezeropointmightchangetotheoutcomethenbeing experiencing,namelysellingdrugsandnotgettingcaughtmakestheper-yearandper-cycledecisiontreesbecomethoseinFigures2aand2b.Thatpeople'sreferencepoints caneasilybeswayed inamannersuchasthis is acentralfindingofprospecttheory.

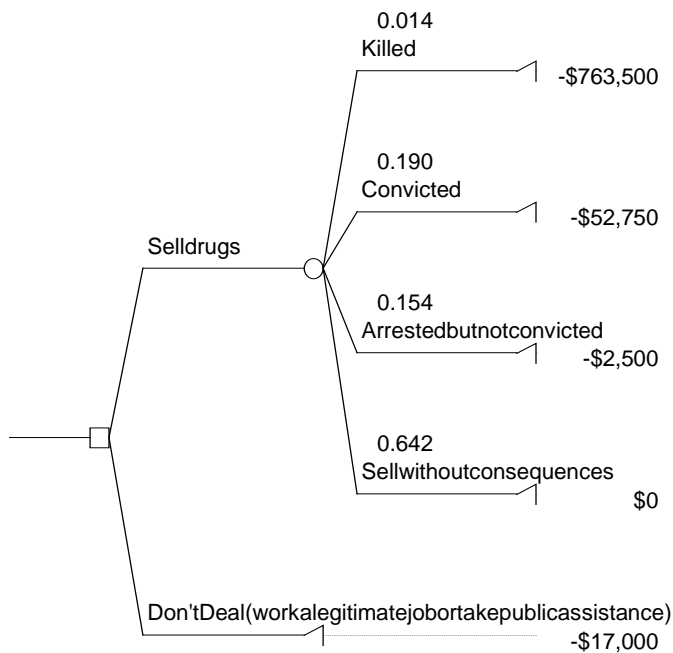


Figure 2a: Tree for Selling for One Year with Zero Point Being Selling Successfully

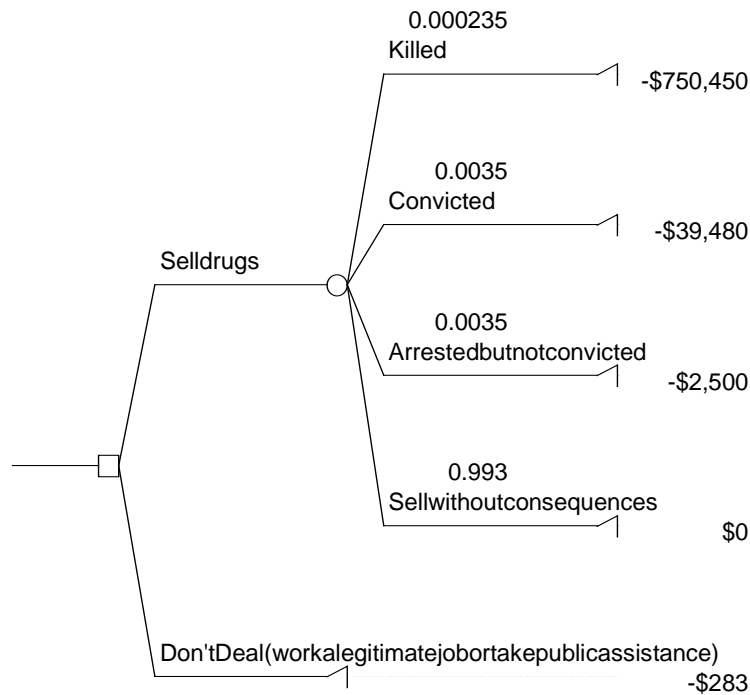


Figure 2b: Tree for Selling for One Cycle with Zero Point Being Selling Successfully

This reframing, or shifting of the zero point, could make dealing on a non-going basis considerably more appealing relative to the alternative because “risk seeking is prevalent when people must choose between a sure loss and a substantial probability of a larger loss” (Tversky & Kahneman, 1992). As Figure 2 shows, when selling successfully is the zero point, the decision to stop selling generates a guaranteed loss. If this tendency to be risk-seeking with respect to losses is strong enough, then the reframing makes selling for a year more appealing than working for a year at another job even if selling for a year would not be preferred in Figure 1a. Indeed, that is the case with all of the simple utility functions mentioned above.

Judgmental Errors and Biases

Even if we are wrong and dealers do integrate risk and outcome information in a completely rational manner, it is highly unlikely that they could accurately assemble the relevant *inputs* to the choice process. The most obvious problem is lack of relevant data. Drug policy analyst slack good estimates of the risks and rewards of drugs selling, and there is little reason to believe individual citizens, through casual induction, could even

approximate the relevant parameters. Furthermore, there are reasons why prospective dealers' estimation errors might not only be large but also be systematically biased in ways that undermine the ability of enforcement to deter dealing.

Availability Heuristic

Prospective sellers might underestimate the average risk of selling because of the structure and complexity of the decision tree. Selling drugs involves a large number of actions, any one of which could go wrong from the dealer's perspective and lead to injury or arrest. The supplier might defraud the prospective seller. The seller might be robbed. Any of the sellers' customers might turn out to be an informant. A sale might be observed by a police officer. People tend to ignore the full range of plausible causes of failure when assessing a course of action, which can lead to significant underestimation of the total probability of failure (Fischhoff, Slovic, & Lichtenstein, 1978; Ofir, 2000).

Also, aspects of the arrest and incarceration process tend to dilute casual observers' estimates of enforcement risks. There is no denying that arrests are often a dramatic, salient event. At the same time, arrests are fairly rare and relatively few citizens witness them. Incarceration, by definition, reduces the visibility of the incarcerated. Thus, dealers who are incarcerated will be less visible than dealers who aren't. Moreover, arrests and incarceration are clustered because police target dealing organizations as well as individuals and they use information from arrests to locate and arrest other dealers. Thus for most people who have not been arrested, the fraction of drug-selling acquaintances who have been arrested will be smaller than the fraction of all sellers who have been arrested. If people estimate the probability of arrest based on the fraction of their friends who have been arrested, they will systematically underestimate their arrest risk. This point is illustrated in Figure 3.

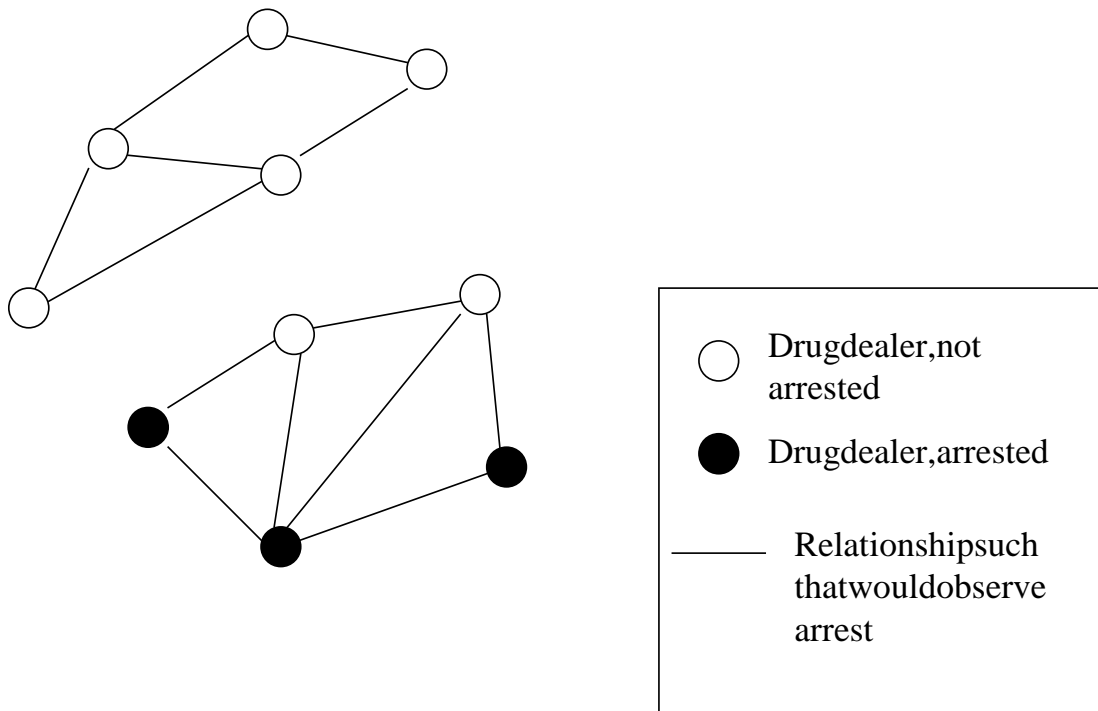


Figure 3: Effect of Clustering of Arrests

Optimism Bias

A second factor that will tend to promote the decision to deal is “optimism bias,” the general tendency of people to have unrealistic optimism about their personal risk of experiencing negative events, even if they have an accurate sense of the risks incurred by people generally (see Weinstein, 1980; Weinstein & Klein, 1996.) A familiar variant is that the majority of drivers consider themselves to be more skillful than the average driver (Svenson, 1981). MacCoun (1993) suggests that drug users and drug sellers are likely to suffer from a similar bias.

Vicissitudes of the Moment

One reason someone might sell for a cycle, even if they wouldn’t sell for a year, is that they have very compelling reasons for needing cash quickly. There may be moments in the chaotic and cash-constrained life of a young adult when the desire for quick cash seems particularly urgent, whether the reasons are dramatic (e.g., owing money to someone who will punish non-payment with physical assault) or pedestrian (wanting to impress a date by spending lavishly).

Intoxication

Perhaps the most obvious source of distorted judgments is that a high fraction of drug sellers are active drug users. This was true even at the height of the crack epidemic when drug selling was arguably at a historical high point; even abstainers who became sellers often later succumbed to temptation and became heavy users (Reuter et al., 1990). Street drug tends to impair the same kind of frontal lobe “executive cognitive functions” that are necessary for rational deliberation and planning (Fishbein, 2000).

Over-Generalization from Early Successes

Suppose that for whatever reason (per-cycle framing effects, intoxication, etc.) someone sells for a few cycles. As mentioned, most likely they would not suffer any adverse consequences. Given that experience, how should such “successful” sellers review the risks of continuing to sell?

In the spirit of Bayesian statistics, one’s posterior probability estimates should combine one’s prior estimate with the new information obtained by having sold without incident. Statistically, limited experiences should provide limited confidence, but people are notoriously insensitive to sample size and tend to give much greater weight to salient personal experiences than to more abstract base rate statistics (Kahneman & Tversky, 1974). Perceptual deterrence studies on petty crimes like marijuana smoking and shoplifting show that offenders who do not get arrested tend to revise downward their estimates of the probability of criminal sanctions (see MacCoun, 1993; Paternoster, 1987). It seems plausible that similar “experiential effects” would occur for drug selling.

Moreover, several psychological and social mechanisms make selling the first time like “crossing the Rubicon.” Psychologically, one has crossed a symbolic moral threshold; once you have sold drugs once, the personal shame of selling a second time is greatly diminished (MacCoun, 1993). There is likely to be a similarly diminishing marginal effect of the public stigma associated with being a drug seller, even if one is not arrested. Indeed, the labeling theory tradition in sociology and psychology would predict that this stigma will push the offender further from mainstream opportunities and relationships and further toward criminality.

Implications for Deterring Other Types of Activities

The foregoing suggests that various cognitive factors can combine with framing to “entice and trap” people into choosing to become regular drug sellers. Note this “trap” stems from the fundamental structure of this decision, not its drug-related context. Hence, if the trap is an important contributor to the prevalence of drug selling, it may also be relevant for other high-risk behaviors such as speeding, driving while intoxicated, using addictive drugs, engaging in unprotected risky sex, and participating in extreme sports. Conversely, insights and intuition developed in those contexts may be informative when analyzing drug policies.

The fundamental structure is the following. We observe that many people repeatedly engage in risky behaviors for which the probability of severe loss per “transaction” is modest but for which the cumulative probability of severe loss from ongoing participation is substantial. In particular, this occurs even when the cumulative risk, coupled with the magnitude of the loss, is so large that it is not easy to explain why so many people engage in the behavior so frequently.

In all these contexts, it is easy to imagine that the first time people undertake such an activity, they are only deciding to “take a chance” “just this once”. They do not necessarily make a conscious decision to abandon their previous pattern of prudent behavior altogether and commit to participating in the risky activity for some number of years. That is, the decision to engage in the risky activity is done at first on a “per transaction” basis.

There are a variety of reasons why someone who would not commit to a risky activity on an ongoing basis might do so for a transaction or two. We introduced one novel, structural explanation that stems from being risk-averse with respect to gains and risk-seeking with respect to losses relative to the status quo, which is the natural reference point (in the prospect theory sense of the word). There are also mathematically less interesting but probably more common reasons (intoxication, peer pressure, extreme moods or circumstances, etc.).

In all likelihood, an individual who decides to take the gamble on a half dozen or so occasions for whatever reasons will suffer no adverse consequences because the

probability of loss on any one transaction, or even on six or ten transactions, is not great. At this point various biases discussed above may take effect (e.g., the salience of the individual's own recent "success" relative to abstract statistics describing frequent failure and the tendency to move the reference point to betaking the gamble and winning as opposed to not gambling). A tendency to be risk seeking in the face of losses may then make the individual decide to persist in the activity.

The Decision to Continue Selling Drugs Even After Receiving a Sanction

The previous section sought to explain why individuals might start selling drugs even if the objective risks of doing so are high. But most people who sell full time for a period of years will eventually get arrested. The risk per cycle is not very high, but the cumulative risk over hundreds of cycles is. When enforcement intensity increases, the number of cycles until the first arrest should go down and the consequences of arrest should go up. Even if enforcement is not very effective at preventing people from starting to sell drugs, why don't people stop selling when they get arrested? Empirically recidivism is common, and at first blush that is hard to understand in an era of severe sanctions.

We offer three classes of explanations. First, we described the choices available to the individual as selling drugs or working at another job, perhaps in the legitimate economy. However appealing working in the legitimate economy was before the individual is arrested, that alternative is likely to be less appealing after. During the months the individual was selling successfully, he or she was probably not building human capital in ways that are rewarded by the job market. Furthermore, arrest and conviction can directly reduce labor market opportunities (Freeman, 1995). Tougher enforcement might even reduce the returns convicted dealers can earn from legitimate work if it stigmatizes them.

Second, the average sanction following arrest for a drug law violation is quite severe, but the mode and median are not. Arrestees, particularly first time arrestees, have a relatively low probability of being incarcerated, even though if they are incarcerated, the sentence can be quite severe.

In particular, in Appendix A we estimate that only half of arrests for drugs sale or manufacture lead to a conviction.⁹ That implies that the modal and median sanction given an arrest is nothing but the arrest itself. Of those who are convicted, only about half are sent to prison, with another quarter sentenced to jail. Furthermore, many drug sentencing statutes have enhanced sanctions for repeat offenders. Since the overall average pool outcomes for first-time and subsequent convictions, this implies that the sanction following the first conviction is even less likely to involve incarceration. In some sense the criminal justice system currently gives drug sellers one or two relatively free bites of the apple (Caulkins & Heymann, 2001). There are compelling arguments for being lenient with first-time offenders. Enhancing deterrence is not one of them.

Most drug sellers may initially fear the consequences of arrest. If they then experience no substantial consequence from an arrest, that arrest might lead them to revise down not up their assessment of overall enforcement risk. That is, even if they revise upward their estimate of the probability of arrest, they might revise down their estimate of the severity of the consequences of arrest. This possibility is merely a conjecture, but there is evidence that the average person over-estimates the probability of arrest and the severity of sanction (see MacCoun, 1993 for a review) and Kim et al. (1993) find that drug offenders who were given only probation upon (second) conviction had a very high propensity to recidivate. So it is at least plausible that an arrest and conviction can lead the seller to see the criminal justice system as a paper tiger – until the conviction that sends the individual away for many years, at which point perceptions and deterrence are irrelevant and incapacitation dominates.

Also, depending on their experiences behind bars, memories of an incarceration experience are likely to be less aversive than either the actor's original expectations, or the actual experiences it occurred (see Frederick & Loewenstein, 1999, for a theoretical analysis and review of relevant evidence; also see Petersilia, 1990). Due to both psychophysical adaptation and social coping, the early period of imprisonment is likely to

⁹Drug sellers are also arrested for drug possession, but the conviction rate for possession arrests is probably even lower.

but the most pervasive form of most inmates. But memories of the event will be strongly influenced by a recency effect.

Finally, for a variety of reasons an adverse outcome after a string of successes might not change behavior as much as a naïve behavioral model might suggest. For one, decision-making experimentation illustrates that individuals exhibit a strong status quo bias, a tendency to remain with a particular alternative even though that alternative may not be the best choice. Related is a confirmation bias that leads people to reinterpret information that appears to be contrary to their prior beliefs, e.g., about the low likelihood of getting arrested. And, people frequently show a self-serving tendency to attribute their successes to skill and their failures to bad luck (Zuckerman, 1979), so sellers may view the failures (arrests) as anomalous events.

Why Prices Might Fall When Enforcement Intensity Increases

The paradox that motivated this paper was the observation that drug prices declined when enforcement intensity increased. The foregoing discussion gave some hints as to why increasing enforcement might have perverse effects, but for the most part it argued simply that prices may not be closely related to enforcement risk. That may help explain an absence of a price increase, but it does not in and of itself explain a price decline.

Recall, though, that there are other factors that would have tended to drive prices down (learning by doing, prices initially having been “too high”, etc.). If the risks and prices model were accurate, one would have expected these factors to be trumped by the effects of increasing enforcement intensity. If, however, cognitive and perceptual limitations vitiate the price raising effects of increased enforcement intensity, then these otherwise second-order effects might become dominant.

That is, the argument there is not that a psychologically more plausible model of the response to increased enforcement is that enforcement has a perverse effect on prices. Rather, the conjecture is that these factors so dilute the impact of enforcement on prices that other factors become more prominent than the “risks and prices” calculations would suggest.

This is perhaps best expressed by returning to and modifying the risks and prices equation. Dividing Equation (1) through by quantity and rearranging yields the classic risks and prices equation for retail prices:

$$\begin{aligned} \text{Retail price} = & \text{cost of drug to dealer} + \text{compensation for opportunity cost of time} \\ & + \text{dollar-denominated production and distribution costs per unit sold} \\ & + \text{dollar valuation of non-dollar risks per unit sold from enforcement \& violence.} \end{aligned}$$

The conjecture raised here is that (1) non-dollar risks may not be fully compensated and (2) there can be a disjunction between the selling price and the total production costs, i.e., there can be a gap or “error” between the left and right hand sides of this equation. Thus,

$$\begin{aligned} \text{Retail price} = & \text{source price} + \text{compensation for opportunity cost of time} \\ & + \text{dollar-denominated production and distribution costs per unit sold} \\ & + \alpha * \text{dollar valuation of non-dollar risks} + \varepsilon, \end{aligned}$$

where α is the attenuation factor describing the extent to which non-dollar risks are not fully compensated and ε is the “error” term. In the language of this new model, the central conjecture of this paper is that $\alpha < 1$. The observation that most of the issues discussed above explain why increasing enforcement might have a diluted but not perverse effect of prices is consistent with a belief that $\alpha > 0$. Theoretically the actual value could be measured empirically from data series on prices and the various right-hand side variables once the error term ε is understood.

However, at present there is no way to model or quantify the error term because it is an theoretical residual. The “risks and prices” paradigm offered concrete predictions about α and ε . In a nutshell, that theory was $\varepsilon = 0$ and $\alpha = 1$. It has been a popular theory not so much because it is universally held to be a good model, but rather because it is almost the only game in town. Unfortunately, if that theory is wrong, there is not another strong competitor standing in the wings.

Conclusion

The “risks and prices” framework gives a clear and plausible argument for why enforcement intensity should be positively related to drug prices. Empirically, however, cocaine and heroin prices have fallen sharply over the last 20 years even though enforcement intensity grew substantially. A variety of factors could help explain this. Here we explore one that has not received much attention to date.

The risks and prices image of individuals moving into and out of drugs selling in a way that balances the expected return from selling and alternative activities makes strong assumptions about human decision making under uncertainty. In particular, it assumes that drug sellers perceive and estimate the relevant probabilities and consequences fairly accurately and that they make choices based on expected payoffs. Research on human decision-making suggests that these conditions are not always or perhaps even often satisfied in practice. To the extent that these cognitive biases and heuristics are prevalent among prospective and active drug sellers, they could help explain why enforcement has not been a more effective deterrent. In particular, if they are sufficiently prevalent, there is no reason why the expected return to drugs selling need bear any particular relationship to the expected return from alternative activities. If decisions to sell drugs are not just biased versions of careful calculations but are actually not well thought out at all, then our conclusion holds with even greater force.

This is not to say that enforcement is completely unrelated to price. There could still be a stochastic relationship. All other things equal, increased enforcement might still be more likely to drive up price, but the linkage might be so weak that materially different outcomes can be observed. Also, enforcement generates tangible costs for drug sellers, in addition to the deterrence-based mechanism of imposing the risk of non-monetary costs. For example, sellers participate in a variety of costly behaviors to avoid arrest. They post look-outs, refrain from selling to customers who look suspicious, minimize their use of fixed locations and assets, etc. Inasmuch as these costs are tangible, immediate, and/or monetary, they are less likely to be under-valued for the reasons discussed here.

Hence, we do not argue that drug enforcement has no value. But the discussion above raises questions, particularly for highly punitive approaches to sellers operating in

markets that are large enough and efficient enough to make it relatively easy to identify potential replacements for incarcerated sellers. If deterrence is undermined by the way risks are perceived, then potential replacements may view the disappearance of their predecessors as a stroke of good fortune, not a sobering warning.

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Appendix A: Modeling the Decision to Sell Drugs

Description of One Cycle

The basic “cycle” of selling drugs involves buying a quantity of drugs from a supplier (or obtaining them on consignment), breaking them down into smaller units, and selling those smaller units. The “Natural History of Crack Distribution/Abuse” project (Dunlap & Johnson 1992, 1996, 1998) is a large ethnographic study designed to develop systematic understanding of crack selling careers. The project involved interviewing many of these dealers. Caulkins, Johnson, Taylor, & Taylor (1999) describe the cycles of the 45 respondents for whom sufficient information was available to fully characterize their cycle. A typical cycle for an independent retail cocaine seller is that of “Robert”. He reported buying \$300 worth of cocaine powder, rocking it up into crack, and making \$750 (\$450 accounting profit) by selling the crack in \$20 unit sizes (i.e., 37.5 sales per cycle). We use Robert’s cycle as the prototypical cycle in our calculations.

Enforcement Risk

The retail value of the US illicit drug market is a little over \$60 billion per year (ONDCP, 1999, p. 113). If the average retail sale is \$30 (perhaps reasonable if average transaction sizes are smaller for street sellers such as Robert than for other sellers), that means there are two billion retail cocaine sales per year.

About 1.5 million people are arrested for drug law violations each year, with about 375,000 arrested for drug distribution.¹⁰ Of those arrested for drug distribution, about half are convicted.¹¹ That suggests an average arrest risk per sale of about $375,000 / 2,000,000,000 = 0.0001875$, and a conviction risk of about 0.00009375.

Of those convicted, 27% receive probation, 22% are sentenced to jail, and 51% are sentenced to prison (Maguire & Pastore, 1998, p. 427). For those sentenced to prison,

¹⁰In 1996, there were an estimated 1,506,200 arrests for drug abuse violations (Maguire & Pastore, 1998, p. 324), of which an estimated 25% were for sale or manufacture (Maguire & Pastore, 1998, p. 363).

¹¹In 1994, there were 181,627 convictions for drug trafficking in US District Courts and State Courts combined, and there were about 365,000 arrests for sale or manufacture (27% of the then 1,351,200 arrests for drug abuse violations). (Maguire & Pastore, 1996, p. 432 and Maguire & Pastore, 1998, p. 421)

the expected time served is 33 months (p. 431). For those sentenced to jail, the average maximum sentence is seven months (p. 430). If 40% of that time is served (which is just a guess) then the average time served in jail by those sentenced to jail is 2.8 months and the average time served per conviction is about $0.51 * 33 + 0.22 * 2.8 = 17.44$ months. (This means the expected time served per sale is about 1.2 hours.)

Reuter et al. (1990, p. 104) report a average net income for a regular street dealer is \$27,000 per year. Robert makes \$450 per cycle, so he would have to execute 60 cycles per year to make \$27,000. That is probably typical of a regular street dealer. Respondents in the crack markets study reported cycle times of "2-3 days", "4-5 days", or "one week".

We use a Bernoulli process model to convert between probabilities of outcomes occurring per sale or per cycle and probabilities of observing that outcome over a longer period of time. The Bernoulli model is almost certainly not accurate. On the one hand, individuals may become more skillful over time as they persist in dealing, so the probabilities of adverse outcomes per act may decline. On the other hand, other risks may accumulate over time. We ignore such possibilities both because we do not have more refined data and because we are interested in illustrating general points with stylized examples, not in computing precise numerical results.

With a Bernoulli model, the probability of being convicted over a cycle that consists of 37.5 sales is $1 - (1 - 0.00009375)^{37.5} = 0.0035$. The analogous probability of arrest is 0.007.

Likewise, the probability of being convicted over a year that consisted of 60 cycles of 37.5 sales per cycle is $1 - (1 - 0.00009375)^{2250} = 19\%$. Recall that the expected time served per conviction was estimated to be 17.44 months. These figures are similar to Reuter et al.'s (1990, p. 104) estimate that a year of full time selling carries a 22% probability of incarceration with an average time served of 18 months.¹² The corresponding arrest probability is 34.5%, so the probability of being arrested one or more times but never being convicted is $34.5\% - 19\% = 15.5\%$.

¹²Our Bernoulli model based on national data suggests only a 14% probability of incarceration, but at time served given incarceration of 24 months. So expressing our model in terms of convictions gives a closer match to the Reuter et al. figures than does expressing our model in per -incarceration terms.

We follow Reuter et al. in assuming a cost per year of incarceration of \$27,000. We assume being arrested but not convicted carries a disutility of \$2,500. The results are not particularly sensitive to this parameter.

Other Parameters

Reuter et al. (1990) estimate that a year of selling carries a 1.4% risk of death and a 7% risk of serious injury. Assigning dollar values to such outcomes is difficult, but to complete their calculations, they use values of \$7,500 per 1% increase in the probability of death and \$30,000 per expected serious injury. We use these figures as well.

To convert these into risks per cycle we employ the Bernoulli model. Setting $(1 - \text{death risk per cycle})^{60} = 0.014$ suggests that the probability of death per cycle is 0.000235. Likewise the risk of serious injury per cycle is 0.00121.

We assume not dealing pays \$10,000 per year and, hence, \$166.67 per cycle.

Decision Tree Describing Decision to Deal

We can now draw a decision tree depicting the probabilities and consequences of the possible outcomes of deciding to sell drugs. To keep the tree from getting too complicated, we simply subtract the expected cost due to injuries from all payoffs. Likewise, although multiple arrests and convictions are possible, we distinguish only between the outcomes of “at least one conviction”, “at least one arrest but no conviction”, and “no arrest” (in addition to the outcome of “death”). When the outcome is “death” we ignore criminal justice sanctions. When the outcome is either death or conviction, we assume the individual made and benefited from half of the sales they would have executed had they neither been arrested nor killed. We assume being arrested but not convicted has no impact on earnings from drug sales.

Appendix B: Prospect Theory

Detailed presentations of prospect theory are available elsewhere (Kahneman & Tversky, 1979, 2000; Tversky & Kahneman, 1992). Here we simply present key features of the formal model.

Value Function

Expected utility theory posits a concave utility function defined on total wealth. Prospect theory posits an asymmetric S-shaped utility function defined in terms of gains and losses relative to a currently salient reference point, often (but not always) the status quo. Specifically,

$$v(x) = \begin{cases} x^\alpha & \text{if } x \geq 0 \\ -\lambda(-x)^\beta & \text{if } x < 0 \end{cases}$$

Empirical estimates suggest that $\alpha = \beta = 0.88$, and that $\lambda = 2.25$. This value function suggests that, *ceteris paribus*, decision makers will be risk averse in the domain of gains and risk seeking in the domain of losses. The λ parameter represents *loss aversion*, the empirically well-substantiated finding that decision makers tend to weigh losses over twice as heavily as equivalent gains.

Decision Weighting Function

Expected utility theory weights outcome utilities by the subjective probability of their occurrence. Prospect theory posits an S-shaped weighting function, roughly an inverted S-shaped function. A simple one-parameter version (Prelec, 2000) is:

$$w(p) = \exp[-\ln(p)^\nu]$$

Empirical estimates suggest that $\nu = .65$, with an inflection point of $1/e$.

The complete, "cumulative" version of prospect theory (Tversky & Kahneman, 1992) no longer applies this weighting function to each outcome separately. Instead, weighting of gains involves "cumulative probabilities" – a focus on the outcome in

question or anything better. The weighting of losses involves "decumulative probabilities" – a focus on the outcome in question or anything worse. There is diminishing sensitivity to outcomes in between the largest gain and the largest loss. We describe this process below, but we note that in the situation we analyze here, it did not qualitatively change any of the conclusions suggested by the original prospect theory formulation.

For losses, $p_1 = w(p_1)$ Biggest loss

$$p_i = w(p_1 + \dots + p_i) - w(p_1 + \dots + p_{i-1}) \quad 2 \leq i \leq k \quad \text{All other losses}$$

For gains, $p_n = w(p_n)$ Biggest gain

$$p_i = w(p_i + \dots + p_n) - w(p_{i+1} + \dots + p_n) \quad k+1 \leq i \leq n \quad \text{All other gains}$$

The value function and decision weighting function, taken together, imply risk seeking for very low probability gains ($p < .05$), risk aversion for larger gains, risk aversion for very small probability losses ($p < .05$), and risk seeking for larger losses.

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