The Dynamic Character of Drug Problems +

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Abstract

This paper makes three points. (1) Drug-related measures, such as the number of users, have changed rapidly over time, suggesting that they are not merely symptoms of underlying trends in the economy, demographics, or other aggregates that change more slowly. (2) Drug markets are subject to a wide range of feedback effects that can induce non-linearity into dynamic behavior. (3) There are at least five classes of epidemic models that reflect such non-linear dynamic behavior. Some of those classes tend to be optimistic about the ability of drug control interventions to reduce use; others are pessimistic. It is hoped that this discussion and, in particular, the typology, can inform and elevate the debate about drug policy, but it is unlikely to resolve that debate because of the inability to demonstrate empirically which class(es) are most accurate.

I. Introduction

The thesis of this paper and, indeed, the conference for which it was prepared, is that drug problems are dynamic phenomenon characterized by non-linearity and feedback. To the extent that this is true, it is important to analyze drug problems with tools that recognize this complexity. Regrettably, most of the literature on drug problems and policies applies linear, static, and/or imprecise models.

This paper proceeds in three parts. The next section gives evidence supporting the thesis that drug problems are dynamic. The following section lists some principal sources of non-linearity and feedback in

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+ This research was partly financed by the Austrian Science Foundation under contract No. P11711-SOZ („Dynamics of Law Enforcement"), core funding from RAND's Drug Policy Research Center which is provided by the Ford Foundation, and by the US National Science Foundation under Grant No. SBR-9357936. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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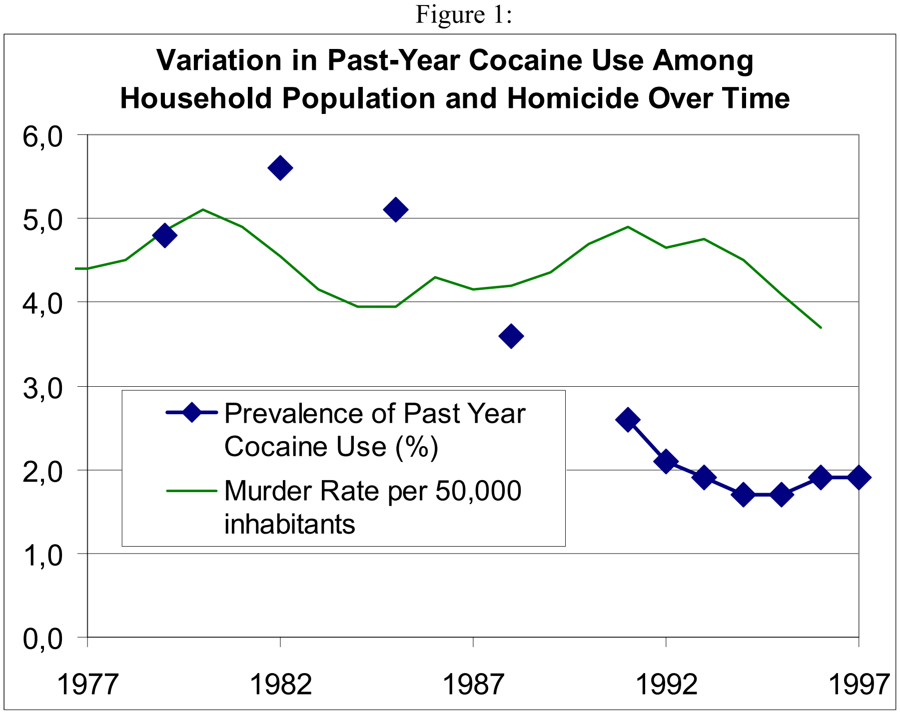
drug systems. The final section offers a typology of five broad types of models of drug epidemics. Which type one believes is most accurate can be an important determinant of one's beliefs about the potential role for policy.

II. Evidence that Drug Problems Evolve Over Time

It is uncontroversial and uninteresting merely to assert that drug use and drug problems evolve over time. A stronger and more interesting argument is that they change more quickly and in more fundamental ways than do most other social phenomenon. Such arguments cannot be quantified precisely, but it is clear that drug-related measures have varied dramatically over the last 25-30 years. Figures 1 – 5 illustrate this point by comparing variation in drug indicators (mostly pertaining to cocaine in the US) with variation in data series that are conventionally viewed as having been far from stable.

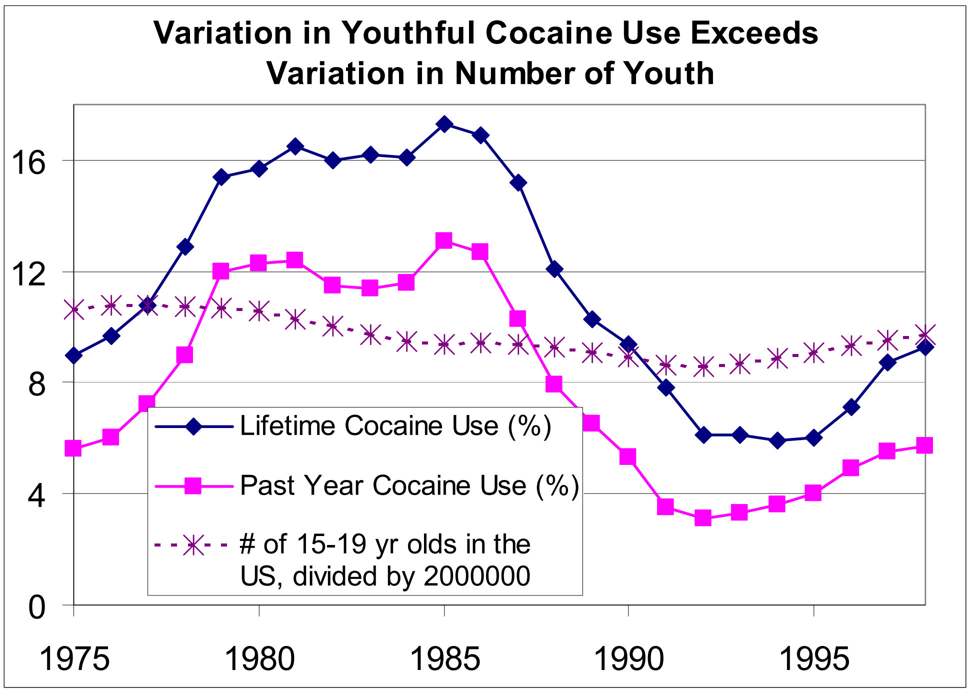
Violence has been described as having an epidemic component, and the US has witnessed sharp changes in the level of violence (Blumstein et al., 2000). Yet Figure 1 shows that variation in the best-measured indicator of violence (the homicide rate) is much smaller than is the variation in the number of Americans who are using cocaine (self-reported past-year prevalence as measured by the National Household Survey on Drug Abuse).

Figure 1:



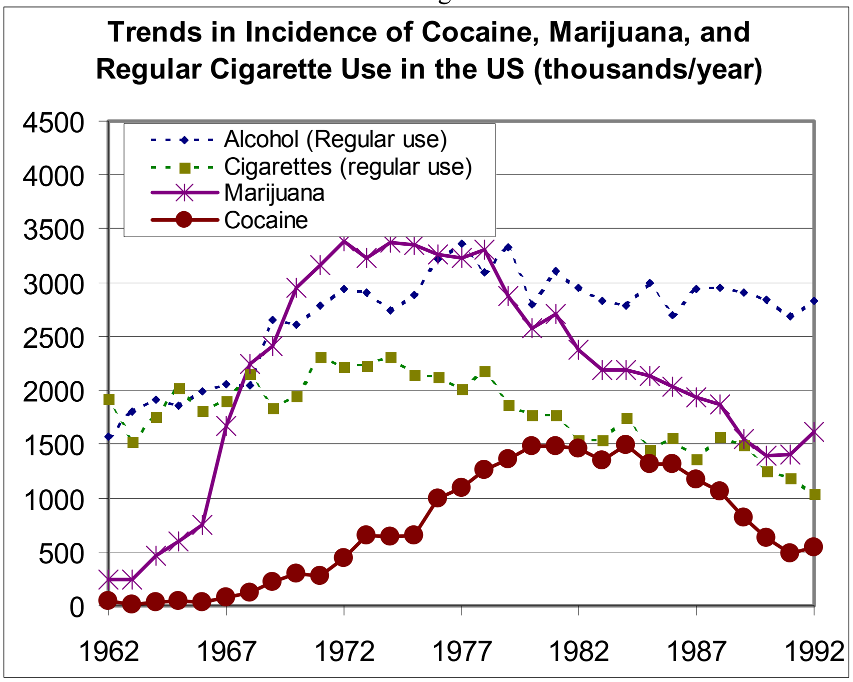
Likewise, much is made of the baby boom and baby boom echo (Mitchell, 1995). Rapid changes in the number of youth have stressed social institutions, been blamed for variation in crime rate, and are correlated with rates of youthful drug use. Yet Figure 2 shows that the magnitude of those variations pale in comparison with variation in the rate of cocaine use by youth (past-year and lifetime prevalence as assessed by the Monitoring the Future survey).

Figure 2:



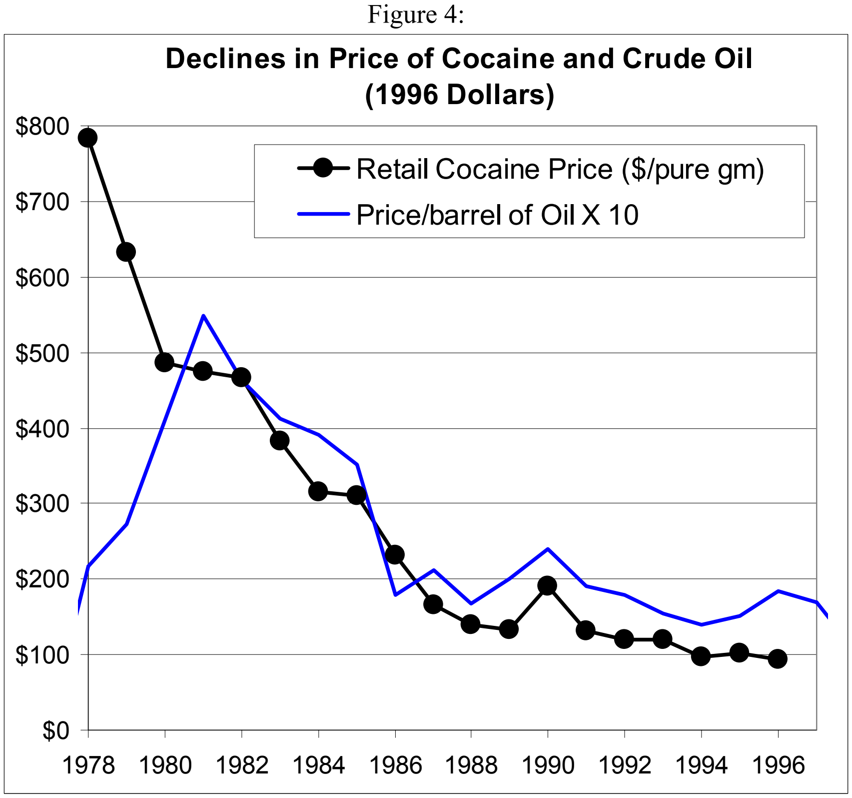
Initiation of illicit drugs also varies much more than does initiation of licit drugs. For incidence as estimated by the National Household Survey of Drug Abuse (SAMHSA, 1997), between 1962 and 1992 the ratios of maximum to minimum numbers of initiates into regular alcohol and cigarette use were just a little over 2:1. For marijuana the ratio was about 15:1, and for cocaine it was almost 150:1. (See Figure 3.)

Figure 3:



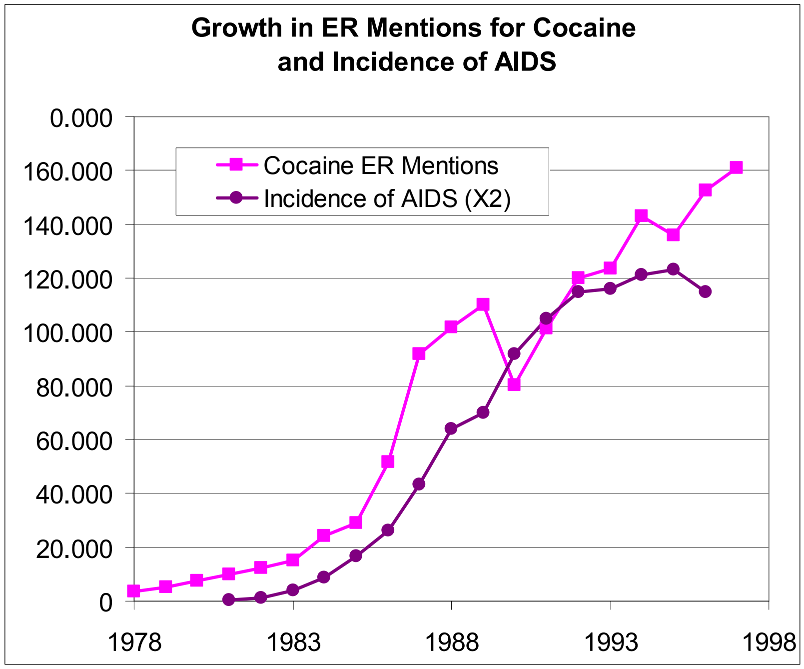
Drug prices have also been unstable. Among licit goods, oil prices are notoriously unstable, being driven to a sharp peak during the oil crisis associated with the fall of the Shah of Iran, and falling sharply in subsequent years. Yet the decline in retail cocaine prices was every bit as steep. (Figure 4)

Figure 4:



And the consequences of drug use have grown sharply over time. It is well known that the rate of new AIDS cases grew from near zero before 1980 to epidemic proportions. The growth in the number of emergency room mentions for cocaine was comparably swift. (Figure 5)

Figure 5



These figures are meant to convey one simple point. Drug epidemics can, and the US cocaine epidemic did, undergo very rapid change over time. None of the axes in these figures are false axes drawn to exaggerate the magnitude of modest changes. More such graphs could be drawn. E.g., Everingham and Rydell (1994) produced an often-cited chart showing how the mix of light and heavy cocaine users changed dramatically over time. In 1980 light users (those using less than monthly) were responsible for about 60% of US cocaine demand; by 1990 that proportion had fallen to 30%. On many dimensions, the cocaine problem of the 1980s was not the same as that of the 1970s, and the cocaine problem of the 1990s was not the same as that of the 1980s.

Looking over a broader sweep of history, Musto (1999) observes alternating periods of greater and lesser drug use. In particular, a cycle of quiescence, rapid escalation, plateau, and gradual decline has been observed for a number of drugs, including powder cocaine in the late 19th and early 20th century (Spillane, 1998) and crack in more recent times (Golub and Johnson, 1997).

Some systems vary over time primarily in response to variation in some exogenous forcing function. For example, the number of flowers in temperate regions varies around the year because of seasonal variation in temperature and amount of daylight. Others generate variation over time because of the character of their internal structure. For example, predator-prey models can generate cycles in levels of both the predator and the prey populations because of internal dynamics. When prey are plentiful, predator populations grow until the drive down the prey population. That can lead to starvation for predators, which allows the prey population to recover and the cycle to repeat itself.

An important question is whether cycles of drug use are driven primarily by exogenous factors (e.g., the business cycle) or internal structures (as with predator-prey models). The fact that drug related phenomenon vary so much more than do many other phenomenon hints that there may be interesting internal dynamics to drug markets and drug use patterns. The next section explores what some of those dynamics may be.

III. Sources of Nonlinearity and Feedback in Drug Systems

Drug related phenomena seem capable of changing much faster than underlying societal characteristics such as economic well-being, demographic variables, or other health-related behaviors. Systems that change quickly often do so because they contain some feedback or non-linearity. This section identifies some likely sources of feedback or non-linearity in drug systems.

Enforcement Swamping

Drug market participants, like people generally, respond to incentives. One important incentive is the risk of enforcement. This risk, in rough terms, is determined by the amount of effort expended by enforcement agencies relative to the size of the market. For example, compare a small city that arrests 100 of its 500 drug sellers per year to a much larger city that has four times as many sellers (2000) but makes only twice as many arrests (200) per year. The *level* of enforcement activity is higher in the second city (200 arrests vs. 100), but the enforcement *pressure* or *intensity* is greater in the first because one-hundred out of 500 is a greater proportion than 200 out of 2,000. In some sense individual market participants do not care how many people are arrested. They care selfishly only about their individual probability of arrest.

Responses to enforcement pressure include reducing the frequency of offending and displacing the activity to another location, drug, or time of day (Caulkins, 1992). In either case, increased enforcement pressure can reduce the number of offenders who are subject to that pressure.

Together these two observations are sufficient to create a powerful feedback effect which Mark Kleiman has dubbed “enforcement swamping” (Kleiman, 1993). Suppose the number of drug market participants increases for some exogenous reason, such as a shift in tastes. The expanded market dilutes the given level of enforcement over a larger denominator, reducing the enforcement pressure experienced by any given participant. That reduced enforcement risk makes it more appealing for others to join the market, which further dilutes enforcement pressure. Depending on the specific circumstances, this feedback effect could grow out of control (possibly “tipping” the market to a new, higher level equilibrium) or it could merely amplify the effect of the original exogenous change.

The same feedback effect can operate in reverse. Suppose the authorities decide to increase the number of arrests. That increases the intensity of arrests, which might induce some people to cease or relocate their drug activities. If so, the resulting reduction in market size further increases the enforcement pressure borne by those who remain, which might in turn encourage still others to exit. Again, this feedback might push the market to a new type of equilibrium (e.g., eliminating the market altogether) or it might merely amplify the effect of the original change in enforcement level, but in either event represents a non-linearity (cf Caulkins, 1993).

Individual Demand is a Function of Past Levels of Consumption

Economists are careful to distinguish two related concepts: demand and consumption. The technical definition of consumption is the same as the lay definition. It refers to the amount of a good produced, sold, and consumed in a market. Demand is different. Demand is not a single quantity but a relationship between price and consumption. It describes how much consumers would want to purchase as a function of price. Typically, consumers would purchase more of a good if prices were low than if they were high. This relationship between the market price and the quantity consumed is often drawn on a graph and referred to as a demand curve.

For many goods, the quantity consumed varies over time with market conditions but the demand curve is stable or if it varies, it varies because of exogenous factors. E.g., the demand for luxury goods may be higher during strong economic times.

For drugs, demand is not fixed. It is a function of past consumption because of addiction and tolerance. The economic interpretation of addiction is subtle and still evolving (cf, Becker and Murphy, 1988), but one interpretation is that past consumption increases the value of future drug consumption relative to the value of consumption of other goods. This manifests in various ways including the observation that as some people become addicted, they spend a larger and larger share of their disposable income on the drug. Thus, drug consumption is reinforcing in an economic as well as a psychological sense.

Tolerance can have a similarly reinforcing effect if users seek out ever increasing doses to achieve the same subjective experience or level of intoxication. Tolerance can also have the opposite effect if it reduces the marginal benefit of a given amount of consumption. Which effect dominates depends on a variety of circumstances, including the type of drug. Anecdotal evidence suggests that tolerance reinforces future consumption for heroin but dampens it for XTC.

Addiction and the positively reinforcing effects of tolerance can create a positive feedback. Suppose supply increases. That has no immediate effect on demand, but would increase consumption. For a conventional good, that would be the end of the story. But for drugs, that increase in consumption can subsequently lead to an increase in demand, which increases consumption still further, which increases demand, and so on. Whether this positive feedback pushes the market to some qualitatively different equilibrium or merely amplifies the effect of the original shift in supply depends on the particular circumstances, but in either case represents a non-linearity.

These demand amplifying effects are not unique to drugs. Goods that are an “acquired taste” (opera is a common example) have a similar character, and network externalities can make demand a function of past consumption. E.g., demand for email grew as subscriptions to email did because the value of email depends in part on how many other people use email. Nevertheless, the fact that there are other exceptions to the “standard” notion of stable demand does not undermine the importance of this feedback for drugs.

Learning by Doing

Economists also distinguish between the quantity supplied in a market (which is the same as the quantity consumed) and the supply curve. The supply curve, like the demand curve, is not a single quantity but a schedule or relation that describes how much suppliers would be willing to sell as a function of the market price. As with demand, for the typical good, the supply curve is usually thought of as stable or as varying only in response to exogenous factors, but for drugs the supply curve can itself be a function of past production because of what Kleiman calls "learning by doing" (Kleiman, 1989).

Learning by doing refers to the idea that the supply curve is directly affected by the cost of production, and production costs decline as suppliers gain experience. The more a supplier organization has produced, the more chances it has had to discover more efficient means of production.

Again, this type of feedback is not unique to drugs. It occurs with many emerging industries, famously the electronic calculator whose prices collapsed as production volumes spurred innovation. Even though drug use has occurred for millenia, the modern illicit drug markets are relatively new. High volume cocaine production is less than 30 years old.

Furthermore, this phenomenon is more pervasive for drug markets because enforcement generates a constant turn over among drug suppliers and supply tactics. At any given time many individual suppliers may be working up a learning curve even as the industry as a whole matures. Incapacitation drives some of this turn over. When experienced suppliers are incarcerated they are replaced by novice sellers. Avoidance plays a role as well. When improvements in enforcement force suppliers to change smuggling routes or tactics, suppliers start over on a new learning curve for that route or tactic (cf Reuter et al., 1988).

These effects can operate at the market as well as the organizational level. If interdiction forces smugglers to use a new transshipment country, initially smuggling may be costly. But if law enforcement agencies in the new transshipment country become corrupt over time, smuggling costs may decline.

The potential for positive feedback loops with learning by doing is clear. The more that is sold, the more efficient suppliers become. The more efficient suppliers become, the lower prices will be, and lower prices induce greater consumption which leads to further learning by doing, and so on.

Initiation is a Function of Current Levels of Use

Drug use is often described as being “contagious”. This metaphor is appropriate even though there is not a physical, pathogenic infection vector as with malaria because initiation rates are significantly influenced by the current prevalence, or level, of use. In particular, most people who start using drugs do so through contact with a friend or sibling who is already using. Indeed, the metaphor of a drug “epidemic” is commonly used precisely because of this tendency for current users to “recruit” new users.

The feedback from current use to initiation is not necessarily uniformly positive. Musto (1999) has argued that, in addition, knowledge of the possible adverse effects of drug use acts as a deterrent or brake on initiation. He hypothesizes that drug epidemics eventually die out when a new generation of potential users becomes aware of the dangers of drug abuse and, as a result, does not start to use drugs. Whereas many light users work, uphold family responsibilities, and generally do not manifest obvious adverse effects of drug use, a significant fraction of heavy users are visible reminders of the dangers of using addictive substances. Hence, one might expect large numbers of heavy users to suppress rates of initiation into drug use.

IV. Types of Epidemic Models

These and other feedback effects permit an almost infinite number of models to be created. Classifying them by mathematical structure (e.g., discrete vs. continuous time models) is of limited value, but one can identify five classes of models based on their explanation of the one empirical regularity concerning drug use about which these is little debate. Rates of initiation and corresponding levels of use have been observed to rise very rapidly from relatively low levels to much higher levels.

As of yet, it is less clear what happens to drug use after this rise. Some evidence suggests that drug use remains at these new higher levels for an extended period of time. E.g., the number of heroin addicts in the US does not seem to have ebbed significantly after its rapid increase in the late 1960s and early 1970s. Some evidence suggests that use falls off from its peak but never returns to its original, low level. E.g., marijuana use in the US is well below peak levels, but remains far above pre-1960s levels. And there is some evidence that the level of drug use can return to quite low levels, at least for a time. E.g., the peak in US cocaine use at the beginning of the 20th century was separated from the current cocaine epidemic by a period (1930-1965) during which use was much less common. Which scenario pertains may depend on the measure of intensity of use (e.g., dependence vs. past-year consumption), as well as type of drug and historical circumstance.

This ambiguity about what happens after an explosion in drug use means that several types of epidemic models are consistent with the minimal facts about which there is clear consensus – namely that drug use can rise rapidly from low to high levels. In particular, there are at least five broad classes of models of drug use.

The first class assumes that drug control efforts drive everything. The internal dynamics of the drug epidemic play at most a secondary role. To people who subscribe to this view, if drug use is low, it is because drug policy is successful. Conversely, if drug use is high, that is evidence of a failure of policy. An explosion in drug use can easily be explained as a precipitous decline in the effectiveness of control efforts. Perhaps understandably, much of the debate among policy makers implicitly if not explicitly adopts this view that policy is central. It encourages evaluating control efforts with simple before and after comparisons. Counterfactuals are irrelevant.

A variation on this class of models assumes that drug use is always threatening to grow exponentially without bound, and the only thing sparing us from having every person or at least every youth using drugs is the control efforts we have in place. This version is a convenient one for agency administrators to adopt when seeking to justify their budgets. It is also not refutable. Recall the old joke about the person who is snapping his fingers. When asked why, he replies "To keep the elephants away." When informed that there are no elephants in the area, he triumphantly concludes that finger snapping is an effective means of elephant control. Likewise, to those who subscribe to this model, the existence of non-users justifies continued funding of drug control efforts.

Given the forgoing discussion of drug epidemics' dynamics and feedback, the reader can safely surmise that I do not subscribe to either variant of this class of model.

The second class of models is as pessimistic about the power of drug control interventions as the first is optimistic. In it, the only stable level of use is a high level of use. Low levels of use are seen as unstable, transient periods. This transient character is reconciled with the observed persistence of low levels of drug use by invoking some exogenous shock. That is, the model is assumed to apply only after some exogenous structural change in conditions. Once that change occurred, the low levels of use were no longer sustainable, and use exploded. For example, one might view high levels of cocaine use in the US as inevitable if there is an efficient supply pipeline connecting the US to source countries in South America. That supply line was tenuous before the 1970s, so use could remain at low levels. Once it was established, use rapidly expanded, and, according to this view, there is little prospect for serious reductions in use without some other exogenous shock to the system (such as elimination of coca production in South America by some blight or fungus).

According to this view of the world, routine drug control efforts are of little consequence once use has approached its high level equilibrium. They might push use down a little, but unless some dramatic intervention manages to alter the structure of the system, control efforts have marginal effects.

Tragler et al.'s (2001) model is of this character, with the exception that when drug use is low, control can suppress it. So, when use is very low, Tragler et al.'s model is like the first class of models. There would be explosive growth, but effective control prevents it. However, when use is high, enforcement swamping vitiates the power of controls.

In the third class of models, there are no users initially but there are many "susceptibles" who are vulnerable to initiation if the opportunity arose. When the drug is first introduced into this population, use rapidly infects everyone who is susceptible, but not everyone is susceptible so not everyone becomes a user. Furthermore, people do not use forever, and susceptible who quit are no longer vulnerable to infection. In the long run, initiation is restricted to people who are newly arrived to the system (e.g., new birth cohorts). Hence, one sees an explosion in use when the drug is introduced to an unexposed population, but that explosion is followed by decay to a lower endemic level as people mature out of drug use.

In these models (typified by Rossi's model described elsewhere in this volume), the dimensions of the epidemic are determined by the proportion of the population that is susceptible and the typical duration of use. Almost everyone who is susceptible will get infected and continue to use for however long people use. Controls that operate on these two parameters are meaningful. E.g., prevention programs that inoculate people against use or treatment programs that shorten drug use careers can reduce the population of drug users. But other interventions tend to have only modest effects, e.g., enforcement may only slightly delay the inevitable explosion in use.

The fourth class, so-called "tipping models," suggests an intermediate degree of optimism about the role of policy. Tipping models are characterized by (at least) two stable equilibria, one at a low level of use and one with a high level of use. Either low or high levels of use can persist indefinitely in the absence of some intervention or exogenous shock. These models view explosions in drug use as instances of "tipping" from the low to the high level equilibrium. Their implications for policy are two-fold. First, policy makers should do whatever they can to prevent the system from tipping from low to high levels of use. Typically that recommendation is of little value because the problem only attracts serious analysis after it has tipped into the high level (problematic) state. Second, modest interventions are unlikely to have much effect, but a truly massive intervention might succeed in tipping the system back to a low level equilibrium, at which point the level of intervention could be cut dramatically without having use return to its high levels. Hence, these models tend to suggest that one should either pursue a relatively modest control program or one should be very aggressive for long enough to tip the system back to its low level equilibrium, at which point control can return to lower levels. Caulkins (1993) and Baveja et al. (1993 and 1997) offer examples of this type of model.

In the fifth class of models, drug use grows rapidly at first because of some positive feedback, but over time, negative feedback effects arise that push use back down. Egan's (1999) journalistic description of the ebbing of New York City's crack epidemic belongs to this class. Behrens et al. (1999, 2000) give a more mathematical example. In it use initially spreads exponentially, but prolonged use leads to adverse consequences that give the drug a negative reputation that suppresses initiation. By differentiating between light and heavy users, this model can endogenously create recurring epidemics of use separated by intervals of low use without invoking exogenous shocks or interventions to generate those cycles. Drug control interventions may or may not be highly valued in these models depending on the details of the model and parameter values.

On the one hand this typology is very useful. When two people disagree fundamentally about the nature of drug epidemics or the efficacy of drug control interventions, it is often because their respective "models" (whether formal or intuitive) belong to different of these classes. Figuring out which classes people subscribe to can cut to the heart of the disagreement.

On the other hand, this typology is not very useful inasmuch as there is as of yet no empirical way of validating one of these classes of models or disproving another. Model validation is tricky in general. In the drug policy domain one faces the added burden of a paucity of reliable data and an inability to run controlled experiments. So those people may simply have to agree to disagree about which class of model is most appropriate.

V. Discussion

Drug use and associated phenomena change rapidly over time. In particular they change much more rapidly than do most other macro-level measures of social conditions, suggesting that these dynamics are to an important degree driven by endogenous not exogenous factors. This empirical observation is complemented by theoretical and qualitative depictions of drug market dynamics.

Particulars of the dynamic evolution of drug use vary by substance, time, and location and data characterizing these changes are relatively weak. Nevertheless, one empirical regularity stands out: drug use can and all too frequently does rise very rapidly from quite low to quite high levels.

This paper defines five broad classes of drug epidemic models that are consistent with such rapid escalation in use. They vary sharply in their implications for the ability of drug control interventions to materially influence drug use. Someone who subscribes to the second class (high levels of use are the only stable condition) may disagree strongly with someone who subscribes to the third class (all susceptibles have a high probability of becoming infected) about whether a new epidemic will ebb of its own accord, and they will disagree about the benefits of drug control interventions not only with each other but also with people subscribing to any of the other classes of models.

Most people implicitly adopt one or another of these classes of models, but few consciously realize they have done so. Bringing more explicit recognition of these models and their implications into drug policy discussions may help resolve differences of opinion or at least concisely identify the sources of disagreement. In the longer run, a concerted effort to refine these models and collect data to support their validation and parameterization could elevate the precision and utility of drug policy analysis considerably.

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