

# **On the Need for Dynamic Models of Drug Markets\***

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## **Introduction**

Markets for illicit cocaine and heroin in the United States<sup>1</sup> appear to be different from legal markets in a number of dimensions: high levels of violence; rapid turn-over of participants; the association, at the individual level, of frequent use and selling; and the large variation of prices and quality in narrowly defined geographic markets at a given point in time. These are not universal characteristics of illegal markets in the United States. For example, the market for illegal gambling services in the 1970s was characterized by stable participation and uniform prices; bookmakers tended to be heavy bettors themselves but that was not true numbers operators. The gambling markets also were subject to light enforcement; see Reuter (1983).

Moreover, the violence, instability etc. are not fixed characteristics of the market for cocaine or heroin but may be sensitive to characteristics of users and sellers (age, relative number of light and heavy users etc.) that change in a systematic fashion, as well as to the intensity and form of law enforcement. This suggests the need for dynamic models, which take into account that these markets evolve in the course of an epidemic and have multi-dimensional responses to policy interventions. Yet the model of “risks and prices” (Reuter and Kleiman, 1986) most used in empirical policy models (e.g. Rydell and Everingham, 1994) is a strictly comparative static model, aiming only to describe the long-run adjustment of a market whose principal distinguishing characteristics are the centrality of enforcement risk and violence by other participants in the determination of prices.

This brief paper attempts to sketch three topics that cannot be handled within the risks and price framework and which seem to lend themselves to dynamic models. They each represent a class of problems, explanatory, policy aiding and conceptual. First, what

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<sup>1</sup> These are the most important illegal drug markets in the US, both by income generated and in terms of social costs.

might explain the persistent long-term decline in prices as these markets develop? Second, how should enforcement resources be allocated over the epidemic between customer sanctions and seller sanctions? Third, what are the determinants of variations in price and purity? Each requires its own modeling approach. I begin with a synopsis of the evolution of the US cocaine market.

## The Evolution of Drug Markets

Drug epidemics, at least for expensive<sup>2</sup> and dependency creating drugs<sup>3</sup>, are characterized by sharp peaks in population incidence rates followed, with a lag, by a plateauing at a new high in the number of dependent users. This pattern reflects the fact that a share of new users become dependent within a few years, that incidence is partly driven by the extent of perceived problem use and that exit from dependence is slow. Everingham and Rydell (1994) offer a now classic representation of this phenomenon, while Behrens et al. (1999, 2000) have explored the dynamics in more detail. Thus drug markets vary over the course of a drug epidemic in: the ratio of heavy users to light users, mean age of users and, in a predictable fashion, the opportunity cost of sellers' time. These in turn affect the level of property crime generated by drug use<sup>4</sup>.

In the early stages of the US cocaine epidemic, users were not predominantly poor. The image of the drug was relatively benign, its dangers little known and attractions great. Most users were inexperienced and not yet consuming large quantities or suffering significant problems. Low income users could earn substantial incomes selling to non-poor users<sup>5</sup>. These conditions are indeed likely to be common in the early stages of drug epidemics with drugs that are little known to the population.

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<sup>2</sup> Price is usually measured per unit weight. Thus heroin, selling at \$500-\$1,000 per pure gram, is more expensive than cocaine, selling at approximately \$100 per gram. However in terms of dose (amount taken in a typical use session), they may be little different. Yet another possible metric, consistent with the rational addiction model of Becker and Murphy (1988) is per annum expenditure or expected lifetime expenditures; cocaine may be more expensive on the first of these and substantially cheaper on the latter.

<sup>3</sup> Marijuana is both dependency creating (with about 10 percent of users self-reporting dependence at some time of their career) and expensive (\$5-10 per gram). However the dependency appears to be short-lived, rarely more than a few years and annual expenditures much smaller than for cocaine or heroin.

<sup>4</sup> Violence deserves a separate treatment. Discussions of violence in drug markets focus on the incentives of sellers as independent agents, either resulting from competition (seeking territorial control) or transactional uncertainty (disagreement about the appropriate quantity of drugs or money). However intra-organizational violence may also have important consequences for the markets. There are two forms of violence generated within organizations; (a) disciplinary violence directed by managers against agents who can either defect with goods or serve as informants against more senior figures and (b) successional violence, the means by which a junior member of the organization may attain leadership.

<sup>5</sup> Reuter, MacCoun and Murphy (1990) report retailers earning \$30 per hour in 1988 in the Washington, DC market.

By the late 1980s frequent users made up a much larger fraction of all users and accounted for a larger fraction of total consumption. They were now poorer and had acquired both a criminal history and a treatment career. More educated users were likely to have responded to messages about the adverse consequences of the drug and to experience better outcomes in treatment. Evidence from the National Household Survey on Drug Abuse (NHSDA) shows that the negative correlation of current cocaine use (past month) and education increased substantially after 1985.

### **The Continued Decline in Prices**

Enforcement responded to increased cocaine use with a lag as would be expected with any problem that emerges rapidly. Reuter (1991) suggests that stringency of enforcement by various metrics (arrests or incarcerations as the numerator; number of users, transactions or sellers as the denominator) may have fallen during the first half of the 1980s as the market expanded. Stringency then increased after 1985 as the market stabilized, at least in terms of quantity consumed. The early decline in cocaine prices is consistent with enforcement swamping<sup>6</sup> (Kleiman, 1993) as well as with the risks and prices framework, with learning by doing reinforcing the effect of lower enforcement pressure (Cave and Reuter, 1988). Both analytic frames have difficulty in accounting for the continued sharp decline until 1989 and the more modest declines of the 1990s, since enforcement stringency rose sharply, over an extended period.

One possible explanation for the time pattern of prices focuses on the changing income of users as well as on risks. Occasional and affluent users may have a low price elasticity, since cocaine expenditures account for a small share of their total expenditures. On the other hand, they may be very sensitive to any increases in risks associated with purchase, such as use of sell and bust operations<sup>7</sup>, or simply higher arrest risks. The opposite patterns may be found with poor dependent users; high price elasticity<sup>8</sup>

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<sup>6</sup> Enforcement swamping grows out of the risks and prices framework. If enforcement risk is the dominant source of costs for drug dealers, then increased volume, *cet par*, lowers cost; this generates the perverse phenomenon of a downward sloping supply curve. (cf. Samuelson, 1973)

<sup>7</sup>“Sell and bust” reverse the usual “buy and bust” tactics. Instead of using undercover agents or informants to apprehend sellers through controlled buys, the police pose as sellers and catch intended buyers.

<sup>8</sup> Caulkins and Reuter (1997) report a number of studies with price elasticities of 1 or more in absolute value. The highest values were obtained with a data system associated with heavy users

(reflecting the dominance of drugs in their consumption baskets<sup>9</sup>) and little sensitivity to changes in arrest and other purchase risks.

Everingham and Rydell (1994) developed a model with Light and Heavy users (L,H) who differed only in their intensity of use. The sketch above suggests a model in which users are classified not simply as Light and Heavy in terms of consumption per unit time but also by income or education. Each group has a potentially different elasticity of demand with respect to price and to other kinds of risks. The simplest useful version of this model has three demand components, L is divided into poor and non-poor, while the H are all poor. The segments are linked in that it is the non-poor buyers whose purchases finance consumption by low income users. The decline in the demand curve of the non-poor then generates a similar downward shift in the demand by poor heavy users, since their income falls.

With a fixed supply curve this generates reduced consumption and lower prices. What we observe instead is approximately flat consumption (quantity) and declining prices (Abt Associates, 1997). The explanation for this may lie in the dynamics of the supply curve. Poor frequent users have three sources of income; legitimate work, non-drug crime and selling to non-poor users<sup>10</sup>. The predicted declines in their incomes from legitimate work may be sufficient to explain the downward shift in the supply curve, given that the marginal return to property crime is presumably declining for any individual.

Turning these verbal conjectures into a formal model that takes account of the changing population of users is a major undertaking. It will require many of the heuristics that have underlain the models developed at RAND to deal with links between demand and supply (e.g. Caulkins et al. 1998) but require more complex dynamic structure to those links. For example, both the probability of moving from light use to abstinence and the elasticity of demand may have to be modeled as a function of user income. However such a model may help generate a parsimonious account of one of the most puzzling aspects of drug markets in the last decade.

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(Drug Use Forecasting). Lower values were obtained with data systems associated with broader populations of users (NHSDA, Monitoring the Future).

<sup>9</sup> On the high share of income going to cocaine purchases, see Needle (1994).

## Choosing Between Buyers and Retailers as Enforcement Targets

The above sketch of market dynamics may also help develop a model for guiding decisions about allocations between buyer and seller sanctions. It is widely assumed that sellers are more culpable, hence the heavier sanctions for those convicted of selling rather than buying or using and the great enforcement intensity aimed at sellers. However it is easy to argue for a reverse hierarchy of culpability when the seller is an impoverished dependent user and the buyer is non-dependent and non-poor<sup>11</sup>. Furthermore, sellers can be replaced; buyers cannot. Indeed, there is regular reporting of sell and bust operations, aimed at closing down specific geographic markets.

I start by noting that the change in the population of frequent users may have increased the share of total expenditures derived from crime other than drug selling through three mechanisms: (1) declines in the fraction of users who are non-poor light users; (2) declining labor force opportunities for low education frequent users, as their addiction and criminal histories made them less attractive to employers; and (3) decreased willingness of families and friends to provide either in-kind support or cash. Since the market had contracted in terms of the number of users, who were now on average poorer, potential drug market earnings of the growing pool of dependent users declined.

We take here that the goal of drug enforcement is to minimize the total harm caused by drug use and drug control. As a first approximation that can be represented as a function of the: Number of light users (L); Number of heavy users (H); drug-related crime other than drug selling or use (CR). Crime is an increasing function of the number of heavy users and the ratio of H/L.

Each light user is at risk of becoming a heavy user. Again, assume that light users have low price elasticity but have high sensitivity to the risk of arrest. A shift from seller enforcement, assumed to raise price, to buyer enforcement, will reduce next period's L; the notional budget here is a fixed total number of arrests. The change in the ratio of H to

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<sup>10</sup> Clearly the poor sell to each other as well. However, for the group as a whole, this is merely redistributive.

<sup>11</sup> It is interesting to note also that for another illegal market, prostitution, Sweden has recently instituted legal reforms which shift all the criminal penalties to the customer rather than the prostitute.

L in that next period will be a function of two parameters, the probability that an L will become an H and the increased flow to abstinence resulting from the shift in arrest activity. Crime will be affected by the same two parameters.

These parameters are not fixed but change in systematic ways over the course of an epidemic. For example, flows from light use to abstinence may be low in the earliest part of the epidemic, increase rapidly and then decline since later recruits have more knowledge of the drug than their predecessors. Thus the optimal allocation of effort may also vary, with a larger share of the budget going to sell and bust operations in the early stages of the epidemic when there are many non-criminal L at risk of becoming criminal H. Later in the epidemic the primary effect on crime may be changes in the ratio of L to H, leading to a shift toward conventional seller enforcement.

This is clearly a highly simplified model. The objective function for enforcement decisions is broader than just crime and prevalence; for example, buyer oriented enforcement may generate markets with lower disorder. Similarly, the budget representation as a fixed number of arrests is a convenient simplification; budgets are more likely to be financial and the costs of the two types of arrests will differ. However, decisions about enforcement strategies if they are to be made on more than an impressionistic basis requires this kind of dynamic modeling.

### **Variation of Prices and Purity**

A prominent feature of drug markets is the extraordinary variation in price and purity. Weatherburn and Lind (1997) report the most detailed data on prices from a single market, that for heroin in a suburban area of Sydney (Australia); about 300 observations over a 2 year period. The range for gram prices in a two-year period was two orders of magnitude, \$118 to \$11,667. Even fortnightly (two weekly) averages for price per pure gram showed dramatic changes, for example collapsing from about \$6,000 in fortnight 7 to \$2,000 in fortnight 11. Similar variation appears to characterize US prices, though no similarly detailed analysis of a specific local market has been published<sup>12</sup>. Models of user and seller behavior should accommodate the enormous uncertainty that they face in

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<sup>12</sup> The STRIDE data allow only analysis at the city level, which is much broader. The Monitor program, providing data only for heroin, does contain the geographic identifiers that would allow analysis of more localized markets but rarely provide more than about 10 observations per quarter.

the cost and purity of transactions, but the “risks and prices” paradigm focuses on expected value calculations.

This price variation is made possible by an odd feature of the market: fixed prices but variable quantity that cannot be readily assessed by the buyer at time of purchase. A dime bag of heroin always costs \$10; it may even always weigh 0.1 gram. But whether it contains 50 milligrams or 2 milligrams of pure heroin cannot be ascertained at time of purchase. Indeed, it may not even be entirely ascertainable after consumption. The diluents may mimic the drug’s effects and the user may have only a general notion of how much of the drug he actually consumed. He will make an assessment of the quality of the experience, but it will have an uncertain relationship to actual quantity.

But if variation is anticipated, users can adapt. One mode of adaptation is to identify sellers who provide predictable quantities of the drug; they may charge higher average prices per pure milligram as a consequence. Prices may still look noisy then because two classes of sellers emerge; one selling at high mean price/low variance and the other at low mean price/high variance. The basis for segregation may be time of day, circumstance and/or place. For example, late night purchases may be lower priced as dealers seek to unload stocks because the market is thinning out and their risks per unit time increasing. Purchases in which buyer and seller are known to each other may have more predictable prices, in part to avoid retaliation by disappointed buyer against seller. Abt Associates, in recent reports of price and purity, note that the heroin market is characterized by bi-modal distribution of pure gram prices.

Buyers’ attitudes toward risk and buyer experience would affect the distribution between the two. Ethnographic reports of continual information exchange among users about the quality of different dealers’ drugs suggests the existence of such heterogeneity. For example, Simon and Burns (1996) describe how some Baltimore heroin dealers distribute samples early in the day to a few experienced users in order to increase demand for that day’s product.

There are more complications though. Buyers and sellers frequently exit the market unexpectedly, as the result of arrest/incarceration or injury/death. In these circumstances it is not clear that the optimal strategy is to develop a strong reputation for reliable selling. In strategic games of repeated interaction, whether it is optimal to



“cooperate” (in this case, sell high quality drugs) or “defect” (sell low quality drugs) depends on the probability the game terminates after any given move (Axelrod, 1984). A seller does not want to exit with any reputational asset remaining and reputations may not be well disseminated any way because of churning among buyers. This does not imply that the optimal strategy is to defraud every customer all the time. If a dealer knows with certainty that he will exit immediately after the next sale, then he should cheat the next customer. But what he can know generally is only the probability of exit; he has a strategic investment decision about how much reputation to maintain and varying attitudes toward risk, as well as variations in assessment of those risks, will lead to price dispersion.

That may drive the market to a low price/high variance equilibrium, with no sellers choosing to provide very predictable quantity. Tougher enforcement may shift this equilibrium to still lower price and higher variability, since the dealer, now with a lower probability of being able to reap the returns on his reputation for, say, the next three months, will choose to take advantage of more opportunities to defraud his buyers<sup>13</sup>.

A small empirical literature shows that buyers of cocaine and heroin usually have substantially more than one supplier (Rocheleau and Boyum, 1994; Riley 1997). This is probably an optimal strategy given the turn-over of suppliers and the fact that so many work part-time. For example, perhaps as many as half of all heroin retailers are arrested in the course of a year; injury and their own drug habit may make them unavailable at other times. But that diversification of sources may limit the feasibility of establishing local monopolies since customers will always be seeking diversification of sources to assure reliable supplies.

That latter point requires elaboration. The customer may only seek to avoid dependence on a single seller; it is sellers rather than organizations that are incarcerated or injured. The customer’s additional sellers may work for the same organization in the neighborhood, so having multiple sources is not incompatible with buying from a single retail organization. However the retail agents themselves also seek diversification of

sources. The incarceration of their principal will force them to seek supplies elsewhere. This would mitigate against broad retail monopolies.

Prices (per pure gram) are determined competitively. If it were really the case that buyers and sellers were anonymous to each other and that the buyer could not ascertain the content of purchases at the time of the transaction, then the profit maximizing strategy would be to defraud every purchaser by providing zero content bundles. The market then would presumably collapse, since buyers over time would seek alternative sources of intoxication.

The market exists; ergo the model is too simple. Even those who buy in truly anonymous transactions and who transparently pose no threat to the seller (the paradigmatic suburban user purchasing nervously in a drive-by inner-city market) receive on average enough of the drug to induce return. One possible explanation is that apparently independent sellers are retail agents for a single organization. The organization has an incentive to encourage return by users to that location; it is locations rather than sellers that develop reputations. There is some evidence of very localized territoriality, perhaps not enough to generate market power given the ease with which buyers can test other location, but sufficient to induce competition through predictability.

This however is a model to be tested, not an assumption to be made. Organizational forms evolve over the epidemic, again perhaps because of variations in enforcement risk and dealer characteristics. In the mid-1980s, as the crack market first appeared in many US cities, it was characterized by relatively modest enforcement intensity, new users perhaps not well known to each other and a low rate of dependence among primarily young users. By the mid-1990s it had changed in all these dimensions; the probability of incarceration had increased substantially, the buyers and sellers formed a stable group (at least over a period of, say, two years, long enough to allow for the average incarceration) and a large fraction of purchases were made by dependent users who had been in the market for 10 or more years. Under these circumstances the optimal price and purity strategy for dealers may vary but it is not obvious how. The greater churning in the later stages of the epidemic creates incentives for cheating but the loss of

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<sup>13</sup> The discount rate of a given user/seller may also vary over time. When his need for drugs is urgent, he may discount hyperbolically, sacrificing all future gains to obtain cocaine or heroin

seller anonymity in a market of experienced participants counteracts this. Modeling this phenomenon will probably require use of dynamic game theory.

## **Conclusions**

Drugs are sold in markets. The prices are determined systematically; notwithstanding the high observed variation they have clear patterns. Moreover, those prices have important implications both for participants and for others, including potential users (affecting their incentives to start use) and society more generally (through crime and the generation of criminal incomes). Understanding their functioning should help inform drug policy decisions in a number of decisions, such as the allocation of control resources between enforcement and treatment/prevention, and of enforcement resources among buyer and seller targeting.

As suggested at the beginning of this paper, markets for some illegal drugs appear to differ in fundamental ways from conventional markets. While the comparative statics methods developed for markets generally may carry over to these drug markets, the dynamic behavior may require new tools.

Analysis of drug enforcement and drug markets has been something of an intellectual outback; a large territory with few occupants in widely scattered settlements. There is a small theoretical literature, detached from any empirical work (e.g. Shah, 199x) and some early modeling efforts with an empirical base (Caulkins et al., 199x). Drug markets will be harder to model than conventional markets, simply because data are so much more difficult to obtain. But more sophisticated modeling of the kind being undertaken by Tragler, Feichtinger, Caulkins and Behrens is an important step in the right direction.

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now. That would also generate price/purity dispersion.

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