

# Illegal “lemons”: price dispersion in cocaine and heroin markets\*

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## ABSTRACT

*The authors examine variability in the price and purity of cocaine and heroin using data gathered over a 14-year period by the System to Retrieve Information from Drug Evidence (STRIDE) of the United States Drug Enforcement Administration. The amount of variability is very great, larger than the variability for any of 15 legal goods for which comparable estimates are available. This raises the question of how such markets cope with the problem of purchasing “lemons”—undesirable or unreliable goods whose quality can not be determined ex ante. Repeated purchases may be an essential part of the answer.*

*Much, though not the majority, of variability in prices per pure gram comes from variation in purity. Conversely, the vast majority of variation in purity does not translate (with positive correlation) into variation in price per raw gram; instead, it translates (with negative correlation) into variation in price per pure gram. Thus, variability in price per pure gram is the “sum” of variability in price per raw gram plus variability in purity. The extent of this variability is curiously stable across drugs, market levels and time.*

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## Introduction

Price dispersion is a characteristic of many markets. It is particularly high in markets for “lemons” (undesirable or unreliable products), such as used cars; in such markets, information concerning quality is costly to acquire. On the

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premise that extreme examples are instructive, the present article examines price and quality dispersion in illicit markets for cocaine and heroin. In those markets, as in Akerlof's classic "lemons" model [1], the buyer cannot observe the true quality of the goods at the time of purchase. However, unlike the classic "lemons" model, illicit drug sellers also usually have only incomplete knowledge of the quality of their goods, since they are not the manufacturers but have purchased the drugs themselves from higher-level dealers without having complete information about the quality. Furthermore, the authorities are actively engaged in suppressing the flow of information by, for example, making it risky for a seller to advertise.

The present article uses transaction-level data on over 145,000 individual illicit drug purchases and seizures; the data had been gathered over a 14-year period by United States Drug Enforcement Administration (DEA) laboratories. Analysis of the data revealed that such illicit markets are characterized by extremely high price and quality (purity) dispersion, apparently higher than that observed in any licit markets. Indeed, the dispersion is so high as to raise the question of how an illicit market sustains itself in the light of (a) opportunities and incentives for defrauding customers and (b) impediments to the dissemination of information. Hypotheses are offered about why illicit markets are able to function in settings that seem to invite the kind of persistent fraud that could lead to their demise.

Variation in price per gram unadjusted for purity is only weakly correlated with variation in purity, so a substantial minority of the dispersion in prices per pure gram (the true effective price) stems from dispersion in purity. Nevertheless, price dispersion falls in a narrower and more consistent range than does purity dispersion. The dispersion of prices is also very high across time, place and purchase quantity.

In the section below, the authors set the context by summarizing relevant findings on the sources of price dispersion in the literature on licit markets. In the next section those sources are related to characteristics of the illicit markets for cocaine and heroin. That is followed by a section on data and methods. The section after that presents the empirical findings. The last section summarizes findings, compare dispersion in licit markets and the illicit drug markets and discuss implications for economic theory and for drug control policy.

### **Insights from prior research on price dispersion and quality uncertainty**

Since Stigler's seminal work [2], published in 1961, economists have observed that, even in highly competitive markets, heterogeneity in the willingness or ability of consumers to search for the "best buy" will allow ostensibly homogeneous goods to be sold for a range of prices in the same market.\* While

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\*Even if every buyer has the same propensity to search, differences in initial information may be enough to generate price dispersion.

sellers who offer the competitive market price may attract consumers most willing to search for the "best buy", sellers who sell at higher prices can still attract consumers for whom finding the "best buy" is too costly [3-5].

In separate but related work, other researchers have investigated the dynamics of markets in which the quality of the goods to be sold may be well known to the seller but is largely unobserved by the buyer. In his classic article, Akerlof [1] described a "market for 'lemons'" in which such informational asymmetry leads to an oversupply of low-quality goods and, in extreme cases, to the disappearance of the market altogether as buyers refuse to enter it. Markets for so-called "experience goods", whose quality is only fully knowable after use, such as restaurant meals, used cars or illicit drugs, are especially vulnerable to the "lemons" principle.

The extreme case where markets actually dry up depends critically on the assumption that the seller's volume of sales is independent of its quality, which tends to be realistic only for markets in which a sale occurs precisely once [6]. The substitution of products of ever-lower quality may be reversed if sellers can make future gains by establishing their reputation for supplying reliable quality and garnering the goodwill of buyers. Given the great frequency with which individual buyers and sellers interact, the article suggests that such reputation effects may be important in cocaine and heroin markets. In licit markets, other mediating institutions may intervene to establish minimum quality standards or to publish data about product quality. These include the civil courts and the ability to sue for fraud, letters to the newspaper, the Better Business Bureau and, more recently, computer chat rooms or bulletin boards.

Prices can differ among sellers for a number of other, more predictable reasons, for example, because sellers have different production costs or supply sources. Numerous studies have documented the existence of price dispersion in markets for licit goods [5], including commercial airline tickets [7], auto insurance [8], fuel [9] and, more recently, books and compact discs (CDs) sold on the Internet [10]. There are very few studies that have examined empirically the "lemons" principle [11-13] or have explicitly focused on underlying measures of quality of goods sold where that quality is largely unobservable by the consumer. There are no known studies that have examined price dispersion in illicit markets.

## **Characterizing the cocaine and heroin markets**

The literature reviewed above is relevant because illicit drugs are, ultimately, consumer goods and, like other goods in modern society, they are provided primarily through markets.

The markets for illicit drugs have distinctive characteristics. For example, the drugs are enormously valuable per unit weight: at retail, heroin costs 30

times as much per unit weight as gold [14].\* These distinctive characteristics have implications. For example, smugglers can afford to employ sophisticated methods to conceal and transport even modest quantities of drugs. Retail purchases are in very small quantities, expressed as either doses or milligrams.

The present article is concerned with those characteristics of illicit drug markets which not only are distinctive but also pertain to price and quality dispersion. The most prominent are: the large number of distribution layers separating producers and consumers; the considerable uncertainty about product quality on the part of both buyers and sellers; the high cost (for both buyers and sellers) of searching and heterogeneity in the willingness of buyers to search for better prices; high and unpredictable turnover among buyers and sellers; and limited ability to signal quality.

### *Multi-stage distribution networks connecting producers and consumers*

Cocaine and heroin distribution within consumer countries are almost purely brokerage activities.\*\* In the United States of America, cocaine and heroin enter the country primarily in large shipments (in the case of cocaine, shipments containing 10-1,000 kilograms). They pass through about five intermediate transactions and are then sold in retail units of 0.1-1 gram. Hence, within destination market countries, all sellers are themselves also buyers. A fascinating implication of this for price and quality dispersion is that some considerations that pertain to buyers (notably their inability to reliably assay drug purity before purchase) may apply to sellers as well as to final consumers.

There are large quantity discounts as drugs move down these multi-tiered distribution networks [16]. The price of cocaine at the point of entry is 15-25 United States dollars per pure gram when sold in bundles of multiple kilograms; at the street level, the price is typically about \$100 per pure gram [14].

Packaging and promotional activities add minimally to costs. Likewise, converting cocaine powder into crack costs very little as a proportion of the value of the drugs converted; this conversion can occur at any market level, but it usually occurs towards the lower end of the distribution chain and almost always within the United States. The drugs are sometimes diluted or adulterated with other ingredients, but the cost of those ingredients and the associated labour involved in "cutting" the drugs are minor relative to the value of the drugs and they are much less psychoactive than the drugs themselves. Hence, prices are most sensibly quoted in terms of prices per pure gram [17], and purity is the most important aspect of quality. There can be other aspects of quality. For

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\*The source of these high prices is presumably the substantial risks of arrest and of victimization by other market participants. Reuter, MacCoun and Murphy [15] estimated that in Washington, D.C., in 1988 a drug dealer faced a 22 per cent probability of incarceration. In addition, they estimated a 1 in 70 annual risk of being a homicide victim and a 1 in 14 risk of serious injury. Those violence-related risks have many sources, including lack of access to civil courts, ready access to guns, valuable property being held by young males and lack of written contracts.

\*\*Cannabis is not included in this analysis because the transaction-level data available do not reveal the potency of the cannabis.

example, "black tar" heroin cannot be snorted whereas "No. 4 heroin" can be either snorted or injected. With respect to quality, the quantitative analysis presented in this article focuses exclusively on purity because it is the best-measured and most important aspect of quality for cocaine and heroin.

### *Uncertainty about quality (purity)*

Transactions, particularly at the retail level, are frequently clandestine and hurried; purchase is the time of maximum exposure to law enforcement risks. In the United States, for example, purchases are usually made in round dollar figures (\$10, \$20) because even the act of returning change is a luxury that persons seeking to avoid detection cannot afford. The existence of standardized dollar purchase units has been observed for over four decades [18].

Though they are natural products, subject only to simple refining, cocaine and heroin are experience goods. The drugs are diluted as they move through the distribution system. At the time of purchase, the retail customer can make only an imperfect assessment of the quantity being purchased and has even less information about the chemical composition of the drug, including its purity and hence its psychoactive effect. Incomplete knowledge of quantity stems simply from the drug's extreme potency; hence, there are tiny quantities involved in retail transactions. One distinction between the retail and higher levels is that it is easier to weigh the larger quantities, both because of the settings in which they are purchased (more protection) and the greater quantities involved.

Not only is the purity of a drug not known at the time of its purchase, but it also may not even be estimated accurately at the time of its consumption. Some adulterants mimic the drug's physical effects (for example, numbing), and the user may have only a general notion of how much of the drug he or she actually consumed, since there is variability in response to the drug, depending on, *inter alia*, the time elapsed since the last drug ingestion and "set and setting" or expectation and context [19]. The user will make an assessment of the quality of the experience, but without certainty. Drug users are thus vulnerable to strategic manipulation by drug sellers, who can reduce the purity of the drugs by adding diluents and/or adulterants.\*

What exactly is in street heroin, how pure is it and what are the effects of different "cuts" (adulterants or diluents)? The answers to those questions are the subject of much discussion on the street. In New York, assays of street-level heroin from a sample of 40 bags found that, in manufacturing the heroin, at least 27 types of adulterants and diluents had been used [18]. These observations are of retail transactions. At the wholesale level, there is in principle more

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\*Not all purity variation is strategic. The mixing of ingredients for retail distribution is done by hand and involves quantities so small that it is difficult to maintain consistent purity. Mixing 1 gram of heroin and 1 gram of lactose (a common diluent) and then attempting to put 10 milligrams of heroin in each 20-milligram packet probably leads to substantial variations in the purity of individual packages. Interested readers might wish to see for themselves just how difficult it is to manipulate 20 milligrams of salt.

opportunity and incentive to conduct systematic testing of purity. However, it is apparently not difficult to sell bundles of varying purity. The fact that testing often appears to be no more sophisticated than having a “taster” snort some to see if the experience is good suggests either a lack of sophistication in a trade that selects for other qualities (such as capacity for violence) or technological difficulties in testing (for example, the time required or ease of manipulation of purity within a bundle or set of bundles).<sup>\*</sup> Fuentes [20], having researched Colombian cocaine-importing organizations in the United States, reported not having heard of any systematic testing (personal communication); refunds and replacements were available for bad shipments.<sup>\*\*</sup> Accurate testing would require a mass spectrometer; not only would it be expensive to purchase such equipment, but it would also create substantial risk of disclosure.

In summary, sellers do not have more than a rough estimate of the purity of the drugs they are selling, however that distinguishes illicit drug markets from the classic “lemons” markets; information is asymmetric (the seller knows whether he or she “cut” the drug), but the person with better information about quality still has only very incomplete information about that quality.

### *High costs of search and heterogeneity in buyers' willingness to search*

Comparison shopping for illicit drugs can entail significant costs. It is time-consuming and it also raises risks of arrest and/or violent victimization for both buyers and sellers.

Willingness to search may vary for a variety of reasons. Some are characteristics of the buyer (new or experienced; frequent or occasional; aversion to being arrested), others refer to the setting of the purchase (indoors or on the street; in the neighbourhood or in distant areas) and yet others represent “intra-individual” variation (whether “stoned” or sober; in regular resupply or while suffering withdrawal). Heavy drug users spend a larger portion of their income on drugs than do casual users and thus may have a strong rational incentive to seek out the best prices. However, the effects of heavy addiction (for example, more acute withdrawal symptoms) may, for various behavioural reasons (such as hyperbolic discounting), lead to a very abbreviated search [22].

### *Turnover of buyers and sellers*

The range of prices and importance of quality uncertainty are affected by exogenous forces, but they may also reflect endogenous strategic interaction between buyers and sellers. A distinctive feature of the illicit drug market is that buyers

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<sup>\*</sup>As reported by a police lieutenant from Newark, New Jersey, “there is a rudimentary chemical test to see if the substance is in fact cocaine and not a fake substitute, such as milk sugar; however, there is apparently no interest in conducting even that test.”

<sup>\*\*</sup>These apparently refer to “intra-organizational” transactions. Manufacturers in Colombia shipped cocaine through a Mexican trans-shipment organization, which then delivered the drug to specific Colombian distribution groups within the United States.

and sellers frequently exit the market suddenly, without giving prior notice to others, as a result of arrest/incarceration or injury/death. Perhaps as many as one half of all heroin retailers are arrested in the course of a year for selling drugs or for other crimes; injury and their own drug habit may make them frequently unavailable at other times. Turnover among personnel in licit enterprises (such as restaurants) can also be high (for example, among waiters), but often the enterprises themselves continue to exist. In contrast, many sellers of illicit drugs are independent operators, and even drug-selling "organizations" have less institutional structure and culture with which to transcend turnover at all but the very lowest staff levels.\*

Perhaps as a consequence, regular buyers of cocaine and heroin usually have more than one supplier; Riley [21], for example, found that, depending on the city, heroin buyers know an average of 10-20 sellers from whom they purchase the drug. High turnover among illicit drug sellers and buyers\*\* should reduce the value of investing in a reputation for "honest" dealing; in strategic games of repeated interaction, for example, whether it is optimal to "cooperate" (in this case, sell goods of the expected quality) or "defect" (sell goods whose quality is lower than what is expected) depends on the probability that the game will terminate after a given move [23]. To the extent that buyers and sellers do not have continuing relationships, the incentive to sell low-quality goods should increase. Hence, all other things being equal, tougher law enforcement may increase dispersion by reducing the value of reputation.\*\*\*

### *Limited ability to signal quality*

Branding is common for licit experience goods. Consider, for example, the brand recognition strategies of restaurant chains. Meaningful branding is rare for illicit drugs perhaps because of the transience of selling organizations and the inability to create legally binding claims to product quality. The exception is retail heroin sellers who stamp "brand names" on their heroin bags. Goldstein and others [25] identified 400 heroin "brands" found in New York between 1975 and 1982. Wendel and Curtis [18] reported that one addict had lovingly collected 175 "brand" labels. A single organization might even sell five or six different "brands" simultaneously.

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\*Prior research suggests that illicit drug markets are rarely subject to monopoly or cartel arrangements; exclusion is too difficult. There may be monopolies over very small geographical areas (a few blocks), but cocaine and heroin markets are generally characterized as either competitive or monopolistically competitive.

\*\*Buyer exits reduce the value of reputation, since some of that is customer-specific. Moreover, each buyer may, through referrals, lead to other buyers.

\*\*\*However, tough law enforcement may lead to the market transforming from a street market into a social-network-based market [24]. Tough law enforcement may drive dealing indoors not purely through law enforcement "swamping" [22]; however, it may also exacerbate the "lemon" problem to the point where the stranger-to-stranger market is not sustainable. Users then revert to trading only with known partners, and it is easier for that to occur within routine activities in social networks than in a place-based market.

However, it is unclear how much meaningful information is conveyed by such stamps. As Wendel and Curtis [18] observed: "The principle of product recognition, however, is undermined by the frequent manipulation of quality and many stamps last only a few days before being replaced. To compensate for this instability and create the illusion that users have choice, many distributors (particularly large organizations which could afford to do so) simultaneously issue several stamps. Users are aware that different stamps do not necessarily mean different heroin and that one of the bags might often be better than the rest."

Similarly, Simon and Burns ([26], p. 65) have noted that, in Baltimore, Maryland, "labels are stamped right on the glassine packet . . . Free testers are tossed out every morning as word-of-mouth advertising for the coming package, and the touts are constantly trumpeting blue-light specials: two for the price of one, or a free vial of coke with every dime of dope." However, the transience of brand reputation is clear: "A product gets a reputation at the beginning of its run, but by the end, the cut takes over and the quality drops precipitously" ([26], pp. 79-80).\*

The authors are not aware of any branding of cocaine powder at the retail level. Crack vials sometimes have caps of different colours, paralleling heroin stamps, and cannabis sellers sometimes describe verbally the source of their supply ("Colombian gold"), but there is little if anything to back up such claims. One reason stamps are not used more widely is that logos increase sellers' risks, since they help police connect a particular user and a seller, a problem that is exacerbated by intensified pressure [18].

Branding may also occur on the heroin market at higher levels. Though there are no data available for the United States, the Australian Bureau of Criminal Intelligence has reported on the branding of kilogram bundles of heroin imported from South-East Asia; at least one dozen brands have been found in the last decade. This is consistent with the claim that testing is difficult and thus purity is unobserved even for high-level transactions.

## **Data and methods**

The data analysed in the present article are from the DEA System to Retrieve Information from Drug Evidence (STRIDE) [27], covering the years 1984-1997. About 75 per cent of the records are the product of investigations involving DEA and the Federal Bureau of Investigation (FBI). Most of the remaining 25 per cent of the records are from investigations of the Metropolitan Police Department of the District of Columbia, the jurisdiction that consists of the capital, Washington. Each observation includes information on the amount paid and the date, city, quantity, identity and purity of the drug, as well as the number of packages into which the drug was divided. A description of the data, including their strengths and weaknesses, is presented below. The results are presented

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\*This might suggest the value of early purchase, while information has value; cash-constrained customers with little self-control and urgent demands will have trouble doing so.

in easy-to-read univariate tables, although multivariate modelling suggests that the distinctions described below along one dimension persist even after controlling for the other dimensions.

The STRIDE database has both great strengths and great weaknesses. Its greatest advantages are that it contains a large amount of transaction-level data from throughout the United States, and it has recorded the data in a consistent manner over many years. Its principal disadvantage is that it is an administrative data set, not one collected for research purposes. For example, it is unbalanced by city and by size of purchase. It is in no sense a representative (let alone random) sample of the market. A National Research Council panel [28] has strongly criticized STRIDE; the use of STRIDE data has also been questioned by Horowitz [29]. However, STRIDE has been used to develop national and local price series that have performed well in a number of uses, such as explaining cannabis use among students in their final year of secondary school [30, 31].

STRIDE data need careful editing. For example, it may be that the collection procedures of DEA and the Metropolitan Police Department of the District of Columbia differ in ways that make it misleading to combine observations from those two sources. Indeed, there is some evidence that the Metropolitan Police are "smarter shoppers" than are DEA agents in Washington, D.C., in the sense that they may pay less for a given amount of drug. Nevertheless, it is clear that the STRIDE price data are not just noise; they are highly correlated with data from other sources, such as the number of drug-related emergency room mentions across cities [31, 32]. That is not to say that the variables are highly reliable; however they may contain some information and, in a field such as drug control policy, where data are so scarce, some information is better than none.

STRIDE does not represent all segments of the market equally. In particular, at the retail end, DEA undercover agents are not known customers of those from whom they purchase drugs, though they may simulate experienced users by their appearance and bargaining behaviour. This perhaps exposes them to higher than average probability of fraud. That is, STRIDE purchases (and perhaps, to a lesser extent, seizures) may have lower average purity than the market as a whole.

As in most administrative data sets, some information results from recording, coding and/or transcription errors. Excluded from this analysis are observations where crucial information, such as the weight of the drug, was missing and where values were so extreme as to be implausible. Table 1 describes the initial sample size and the number of observations excluded according to specific criteria for each of three drug types (cocaine hydrochloride, cocaine base and heroin) for the years 1984-1997. Specifically excluded are all observations from outside the United States, all observations where the raw weight was less than 0.02 grams, all transactions where the expenditure was less than \$10 and all observations where the price per pure gram ( $\text{cost}/(\text{weight} \times \text{purity})$ ) was less than \$10 or greater than \$5,000 for cocaine (\$10,000 for heroin). The last exclusion was conservative in that it reduced measured variability but excluded a small number of wholly implausible combinations of price and purity.

Table 1. Sample characteristics, 1984-1997

Category	Cocaine hydrochloride	Cocaine base	Heroin
Total observations	99 388	66 693	48 348
Exclusions			
Foreign	-12	—	-11
Raw weight <0.02 g	-4 471	-4 095	-2 796
Expenditure <\$10	-41	-36	-16
Price per pure gram <\$10	-234	-154	-56
Price per pure gram >\$500	-581	-837	-1 713
Total exclusions	-5 339	-5 122	-4 592
Percentage excluded	(-5.40%)	(-7.70%)	(-9.48%)
Total included observations (seizures and purchases)	94 226	61 632	45 017
Total included seizures	63 249	39 022	28 740
0% purity	-3 085	-2 111	-2 270
≤ 2% purity	-3 233	-2 211	-2 766
Total included purchases	30 977	22 610	16 277
0% purity	—	—	-1 051
≤ 2% purity	-6	-5	-1 375
Local (District of Columbia) police seizures and purchases			
Seizures	-5 400	-23 535	-8 446
Purchases	-1 228	-6 400	-1 806
Total	-6 628	-29 935	-10 252
Total included observations, excluding local (District of Columbia) seizures and purchases and excluding ≤ 2% purity	84 598	30 111	31 659
Total included purchases, excluding local (District of Columbia) seizures and purchases and excluding ≤ 2% purity	29 743	16 205	13 254

The above-described procedure resulted in the exclusion of 5.4 per cent of the cocaine hydrochloride observations, 7.7 per cent of the cocaine base observations and 6.9 per cent of the heroin observations. Most of the exclusions were made because the recorded weight was less than 0.02 grams. In addition, for analyses where data from many localities were grouped together, data acquired by the Metropolitan Police Department of the District of Columbia were excluded. The main reason was that the data gathered by the Metropolitan Police Department accounted for such a significant share of the total data set (7 per cent of the data for cocaine hydrochloride, 48 per cent of the data for cocaine base and 22 per cent of the data for heroin) that any aggregate summary statistics of the whole sample would be too heavily weighted towards the features of the market in the District of Columbia, including those features which might arise because the Metropolitan Police Department, in acquiring its samples, might be using techniques differing from those used by federal agencies. The remaining data set was more evenly weighted across cities and only contained samples acquired by federal law enforcement agencies, namely FBI and DEA, including those acquired in Washington, D.C. Excluding the data described above, the Metropolitan Police Department samples and those with a purity of less than 2 per cent, there were 84,598 cocaine hydrochloride records (of which 35 per cent involved purchases), 30,111 cocaine base records (of which 54 per cent involved purchases) and 31,659 heroin records (of which 42 per cent involved purchases).

The main focus of the analysis presented in this article is the degree of variability in the purity and price per pure gram for both cocaine and heroin. Cocaine appears in two forms: "cocaine hydrochloride", usually referred to as cocaine powder, and "cocaine base", most commonly in the form of "crack".\* For analysis of purity the authors included data on purchases and seizures, but only data on purchases could be used to derive prices per pure gram.

For a significant proportion of seizures, the recorded purity level was "zero", but it was impossible to accurately distinguish samples actually containing no psychoactive substance from those cases where there was merely a failure to assay the purity of the samples or to record it properly. Again, the authors adopted a conservative approach in excluding samples where the recorded purity level was less than 2 per cent, in order to avoid both samples with "zero" purity and those with extremely low values that might be transcription errors. The net effect was that the analysis should slightly understate the true variability of purity.

STRIDE records the number of separate packages into which each seizure or purchase was divided. For purposes of analysing purity by the weight of the transaction, the authors assigned a level of purity to the average weight per package but not to the total weight. However, for subsequent analyses of retail quantities and prices by year or across cities, the total weight was used.

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\*"Crack" and "cocaine base", the codes used in STRIDE, are not identical. Free-based cocaine might be classified as "base", and that probably accounts for most of the few observations in this category in the early 1980s. By the mid-1980s, crack, being a more efficient mode of obtaining a quick and intense high, had supplanted earlier forms of cocaine base.

## Methods

### *Calculation of pure gram price*

Price was measured in terms of dollars per pure milligram (actual recorded expenditure  $\div$  (recorded weight  $\times$  purity)). That value was an approximation, since total weight might have hedonic value as well: 200 milligrams of pure cocaine contained in 500 milligrams might provide a slightly different experience than if it were contained in 1 gram. It was assumed that that is a second-order effect.

### *Measures of variability*

There is no single convention for describing the variability of a particular statistical distribution, especially when that distribution is not symmetric, nor is there a single convention in the empirical price dispersion literature. Therefore, a number of measures were analysed for both purity and pure gram price, as well as the full shape of the underlying distribution not readily captured in the summary statistics; these included the coefficient of variation (standard deviation divided by the mean), the interquartile range divided by its median, the standard deviation of the logged values (which, especially for prices, tended to be normally distributed) and the Gini coefficient. There was a very high degree of correlation between the various measures. The Gini coefficient is emphasized because it provides a convenient interpretation: twice the coefficient gives the absolute difference in price (purity) as a proportion of the mean price (purity) to be expected from two observations drawn at random from the population.

In order to reduce the influence of extreme outliers that might be the result of administrative errors in the data (implausible combinations of weight, purity and expenditure not already excluded by the conservative procedures described above), measures of variability for the price per pure gram were calculated only for the range of values between the 5th and 95th percentile. That, again, would tend to understate price dispersion and thus, was conservative with respect to the central conclusion that dispersion was very large.

## Findings

### *Substantial price and purity variation for cocaine and heroin*

The main descriptive finding was that the markets for cocaine and heroin were characterized by extremely high dispersion in purity and price, particularly when compared with licit goods. Table 2 contrasts the coefficient of variation in prices for cocaine and heroin with those for licit goods as reported in a number of studies.

Table 2. Comparison of price dispersion measures

Category	Product	Coefficient of variation
<b>Panel A. Various studies: reported coefficient of variation in retail prices</b>		
Pratt, Wise and Zeckhauser (1979):		
Boston area <sup>a</sup>	Paint	0.071
	Mufflers	0.173
	Cameras	0.090
	Fuel oil	0.289
	Stationery	0.060
	Lumber	0.130
Treno and others (1990): California <sup>b</sup>		
	Beer	0.190
	Wine	0.340
	Spirits	0.240
Walsh and Whelan (1999):		
Irish grocery stores, 1992-1995 <sup>c</sup>	Mineral water	0.077
	Sugar	0.107
	Coffee	0.126
	Bacon	0.058
	Tea	0.038
	Dog food	0.144
<b>Panel B. Illicit drug markets, STRIDE data for the period 1984-1997</b>		
Average coefficient of variation		
in retail prices observed in		
any given year	Cocaine hydrochloride	0.755
	Cocaine base	0.476
	Heroin: "high-purity cities"	0.661
	Heroin: "low-purity cities"	0.630
Average coefficient of variation		
in purity of retail quantities		
observed in any given year	Cocaine hydrochloride	0.331
	Cocaine base	0.218
	Heroin: "high-purity cities"	0.520
	Heroin: "low-purity cities"	0.800

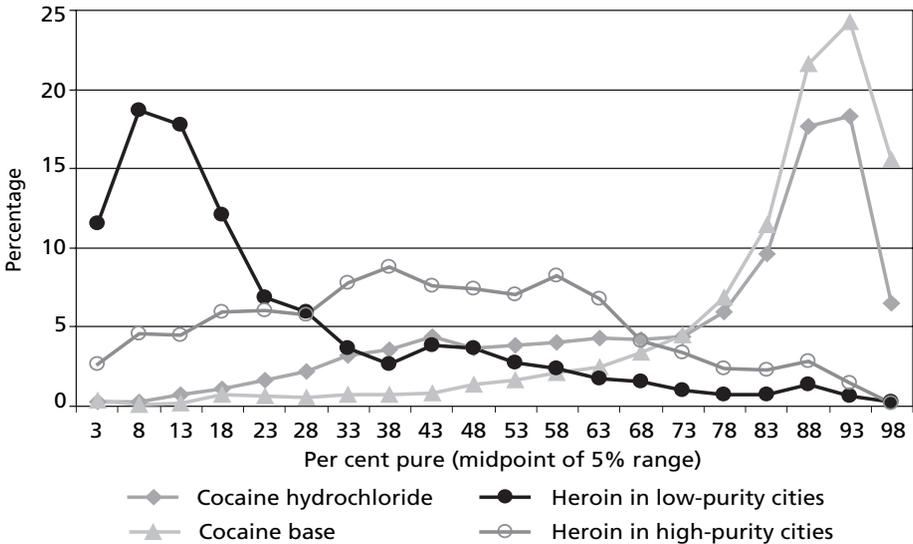
<sup>a</sup>John Pratt, David Wise and Richard Zeckhauser, "Price differences in almost competitive markets", *Quarterly Journal of Economics*, vol. 93, No. 2 (1979), pp. 189-211.

<sup>b</sup>A. J. Treno and others, "Alcohol beverage price spectra: opportunities for substitution", *Alcoholism: Experimental Research*, vol. 17, No. 3 (1993), pp. 675-798.

<sup>c</sup>P. P. Walsh and C. Whelan, "Modelling price dispersion as an outcome of competition in the Irish grocery market", *Journal of Industrial Economics*, vol. 43, No. 3 (1999), pp. 325-343.

The data for both cocaine and heroin were divided into two groups. STRIDE distinguishes between "cocaine hydrochloride" (cocaine powder) and "cocaine base". For the years analysed, "cocaine base" was primarily crack. The heroin observations are divided into two groups by location, because there were striking differences in purity across two groups of cities. As shown in figure I, the interquartile range of heroin purity in "low-purity cities" was 6-29 per cent, whereas for "high-purity cities" the range was 29-59 per cent.

**Figure I. Distribution of purity, retail quantities, by drug type, 1987-1991**



The licit goods included some that were very homogeneous (e.g. sugar and tea) and others that were highly differentiated (e.g. wine and cameras). The price of wine was expressed in dollars per ounce of ethanol, but there was little variation in the alcohol content of different wines; the differences were in observable and moderately well-signalled quality. Low-priced table wine is not sold in the same market as an expensive bottle of fine wine from a well-known wine-producing area.

None of the licit goods except sugar could claim to be as undifferentiated as cocaine and heroin if their purity were observable. Yet only the highest coefficient, 0.340 for wine in California, approached the range of coefficients of variation for any illicit drug. The lowest observed average coefficient of variation for illicit drugs was higher than those for all 15 licit goods.

Few empirical studies have dealt explicitly with variability of quality, so it was hard to compare the range in purity of illicit drugs with the counterpart dimensions of other goods. Indeed many licit goods, including alcohol and prescription drugs, have quite strict controls on the purity of active ingredients,

thus constraining quality variation. On the other hand, some reports on unregulated but extremely popular herbal supplements, such as St. John's wort or ginkgo biloba, suggest that the possible range of ingredient quality is quite high [33].

The amount of variability in the purity of illicit drugs is striking. The degree of variability in purity was highlighted by analysing the distribution of purity for a typical drug purchase of \$100 (the modal expenditure in the STRIDE data). Figure I shows the histogram for each of the four types of illicit drugs for the period 1987-1991. The distributions for the various drugs are different, but all show large variability.

Much, though not the majority, of the variability in prices per pure gram comes from variation in purity. Conversely, the vast majority of variation in purity does not translate (with positive correlation) into variation in price per raw gram; instead, it translates (with negative correlation) into variation in price per pure gram. Looking at it another way, price per raw gram is highly variable and is very weakly correlated with purity, so variability in price per pure gram is the "sum" of variability in price per raw gram plus variability in purity. This is consistent with the expected purity hypothesis of Caulkins [34].

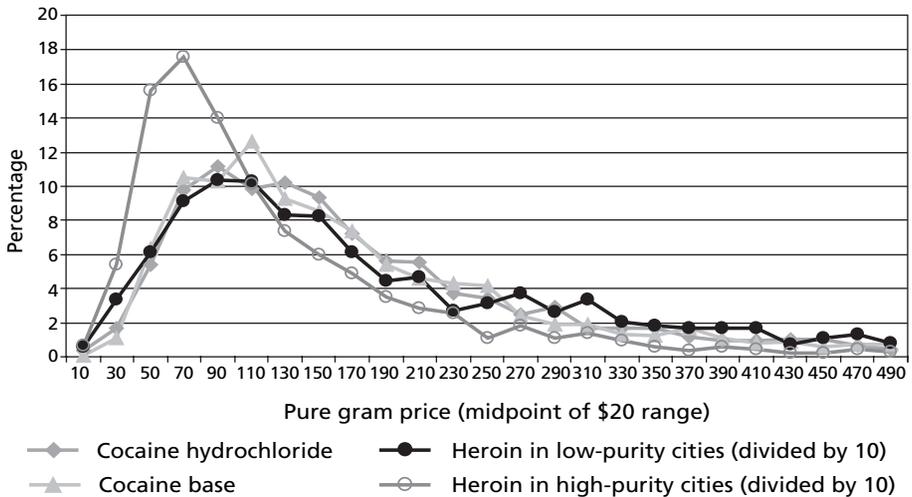
The variability in price and purity might simply be an artefact of combining heterogeneous but much less variable profiles of distributions from many cities. Or, if there were significant seasonal factors influencing purity, measuring over a single year or several years might again combine distinct but much less variable periods. Tests for seasonal and yearly effects, as well as day-of-week effects, in purity and price found none. Moreover, the variability did not seem to come primarily from systematic "within-period" price variation (i.e. price spikes).

Another omitted variable explanation was that there might be multiple distinct markets within a single city that were being combined, but (a) the lack of correlation between purity and price per raw gram undermines theories of distinct low-price/low-purity and high-price/high-purity markets and (b) the lack of correlation across cities between price variability and city size cast some doubt on the idea that this market aggregation story was the true explanation for most of the apparent variability. If it were, larger cities would be expected to display greater variance because they could sustain more different markets.

### *Curious stability in the amount of variation in illicit drug prices*

There were noticeable differences in the variability of purity by drug, market level, time and place. In contrast, price dispersion, while very high, was highly stable over transaction size, time and drug (though not necessarily city). Particularly striking was the closeness of the retail price distributions for all four drugs (heroin being divided between "low-purity" and "high-purity cities") and their approximation to a log-normal curve. (Compare figure II with figure I.)

**Figure II. Distribution of pure gram prices, retail quantities, by drug type, 1987-1991**



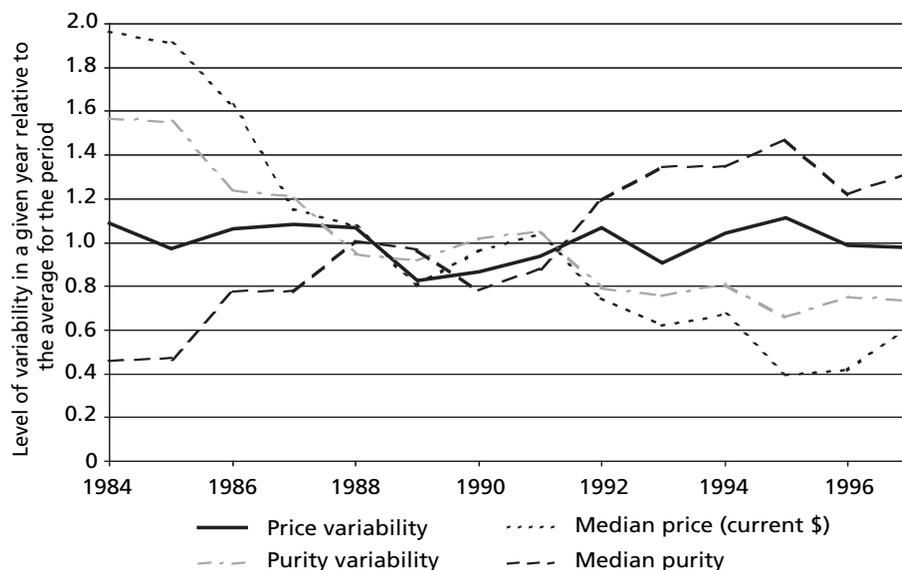
Purity was not consistently less or more variable than price: crack purities were less variable than any price measure; heroin purities in “low-purity cities” throughout the 1980s were consistently higher.\* Instead, for all three categories of drugs in powder form (heroin of both low and high purity and cocaine) in almost all years, the Gini coefficient for price variation was between 0.28 and 0.38. For crack, the coefficient was almost always between 0.2 and 0.3.\*\* For purity, there was low and stable variability for crack (0.08-0.15), moderate and stable variability for cocaine powder (0.15-0.24) and declining variability for heroin of high purity (0.47-0.21) and even for heroin of low purity (0.47-0.37 or so).

The stability of the Gini coefficients for price variability was all the more striking when considering how much changed in illicit drug markets during the period under review; for example, purity varied enormously for the cities with high-purity heroin, increasing from nearly 20 per cent to 60-70 per cent purity.

\*The differences in the variability of purity across drug types may reflect the nature of that particular drug and its appeal. Heroin purity is truly heterogeneous, while crack is fairly uniform, perhaps because drugs in powder form are easier to dilute than are “rocks” of crack. This may help to explain the popularity of each drug. Potential crack users can be fairly confident about the potency of their drug of choice. Potential heroin users, however, must contend with the strong possibility that the drugs they buy will be either too potent, leading to risk of overdose, or insufficiently potent, leading to continued craving. The emergence of heroin of very high but less variable purity may have helped boost the popularity of that drug in the late 1990s.

\*\*More specifically, there was little variation across years for heroin in either “high-purity cities” or “low-purity cities”; the range of Gini coefficients was 0.280-0.381. Cocaine base also showed moderate variation and no trend after 1987; the range was 0.212-0.342. The large coefficients were from earlier years, when crack was just entering the market. From 1988 to 1997, the range was only 0.212-0.296. For cocaine powder, there was substantial variation (0.289-0.449) but no trend. Cocaine in both forms showed a spike for 1990, the year of the crackdown on the Medellín cartel. Though heroin prices increased at that time, the variability did not.

**Figure III. Heroin in "high-purity" cities: stable variability in price, 1984-1997**



That change in median purity apparently greatly affected the variability in heroin purity and the median price per pure gram of heroin, which fell by 75 per cent even before adjusting for inflation, but the variability in heroin prices was stable throughout. (See figure III.)

The exception to this rule was crack. Variability in crack prices tended to decline between 1985 and 1997, while variability in crack purity showed no consistent trend, first decreasing and then rebounding.

It was also not the case that variability was constant across locations; for example, among cities with adequate data (50 or more observations between 1987 and 1991), Gini coefficients were tightly clustered across locations for heroin prices (0.218-0.308), cocaine purity and both price and purity of crack. Gini coefficients were diverse for cocaine prices (0.092-0.555) and heroin purity (0.171-0.308).\* A striking and unexpected result, however, was the overall tendency for the Gini coefficient for variation in price to be quite consistent across drugs, time and, as shown below, market level.

### *Differences (and lack of differences) across market levels*

There is not one market for illicit drugs but many markets, differentiated by transaction size. Transactions involving 1 kilogram of cocaine (valued at roughly \$25,000) differed from transactions involving 0.2 (pure) gram (valued at roughly

\*There was no consistency in price variability across cities for different drugs, with a rank correlation in price variation of only 0.33 between cocaine powder and crack and 0.02 and 0.03 for cocaine powder and heroin and for crack and heroin, respectively.

\$20) in terms of location, type of participants, stakes and many other aspects. It was hypothesized that there would be less dispersion in both prices and purity at higher market levels, where incentives and opportunities for verifying the quality of the drugs or the seller were greater. The expectations were generally confirmed for purity but not for price.

Moving down the distribution chain from larger wholesale quantities to small retail amounts, the median purity of heroin and cocaine powder declined as various diluents and fillers were added to the product. The degree of variability increased commensurately (see table 3).\*

Table 3. Price and purity levels and variability by market level

Weight category	Gini coefficient				Median			
	Cocaine powder	Cocaine base	Heroin of low purity	Heroin of high purity	Cocaine powder	Cocaine base	Heroin of low purity	Heroin of high purity
					<i>United States dollars</i>			
<b>Price per pure gram</b>								
1kg+/1kg+	0.226	0.363	—	—	22	34	—	—
125-1,000g/100-1,000g	0.228	0.235	0.365	0.306	32	50	396	301
35-125g/10-100g	0.216	0.188	0.338	0.311	52	51	614	440
4-35g/1-10g	0.253	0.234	0.339	0.318	69	71	1 166	785
1-4g / 0.5-1g	0.300	0.268	0.353	0.348	132	125	1 507	892
<1g / <0.5g	0.395	0.329	—	—	209	167	1 235	1 005
					<i>Percentage</i>			
<b>Purity</b>								
1kg+/1kg+	0.063	0.283	0.205	0.185	89	64	74	83
125-1,000g/100-1,000g	0.099	0.176	0.342	0.248	87	75	51	62
35-125g/10-100g	0.139	0.140	0.415	0.312	84	82	28	47
4-35g / 1-10g	0.156	0.122	0.475	0.289	81	85	20	55
1-4g / 0.5-1g	0.171	0.099	0.441	0.369	81	88	20	36
<1g / <0.5g	0.173	0.095	0.444	0.289	83	89	14	43

\*The moderate levels of heroin purity observed at high wholesale levels contradicted the orthodoxy about heroin markets. Since bulk is a principal source of law enforcement risk, high-level dealers have an incentive to minimize exposure by transacting in high-purity drugs. Yet there was clear evidence of "cutting" close to the import levels of the heroin trade. In the data analysed, cities with high-purity heroin, 10 per cent of observations involving 1 kilogram or more had a purity level of less than 27 per cent. This has also been reported in recent studies of markets in Frankfurt and Milan [35] and in Britain [36]. Cocaine shows much less purity variation at this level; the 10th percentile is 74 per cent and the 90th percentile is 93 per cent. On the other hand, except for the first two levels of low-purity heroin distribution, the drop in median purity was never consistent with an image of most dealers cutting drugs with 1 unit of diluent per unit of drugs, or even 1 unit of diluent per 2 or 3 units of drugs. Dilution is, on average, much less extreme.

Curiously, the median purity of cocaine base increased as it moved down the distribution chain and also became significantly less variable. That might be the result of STRIDE not differentiating between crack per se and other forms of base, such as the base produced as an intermediate product at the source, the Andean subregion, which might be more common at higher market levels.

What was striking, however, was that, despite the vast differences in the total dollar expenditure at various levels in the distribution chain, the amount of price dispersion at each market level was roughly the same for heroin in both "low-purity" and "high-purity cities". The price per pure gram was as variable at the level of 100-1,000 grams as for quantities of 20-1,000 grams. For both forms of cocaine there was more variation at the retail level than at higher levels, but not enormously more.

### *Relationship between variability of purity and pure gram prices*

The authors hypothesized that demand for an illicit drug would be negatively related to the variability of its purity, since unobserved quality variation would create undesirable uncertainty. For retail quantities of each drug type and combination of year and city, the authors calculated the median, mean and standard deviation of purity and price (or log price) and then the aggregate coefficient of variation. Using a fixed effect estimator to control for city and excluding city years with fewer than 10 observations, the authors estimated the effect of median purity level and variability of purity on expected median of pure gram price (and log pure gram price).

It was found that median price in a given city and year was negatively related to median purity. For quantities at retail levels, increasing purity decreased the pure gram equivalent price, confirming the conventional wisdom.\*

The effect of purity variability was to increase pure gram prices, contrary to expectations. The same model was estimated separately for cocaine powder, crack cocaine and heroin because they have varying degrees of purity dispersion, heroin and crack being at the extremes. The relationship of purity variability on price was still positive but more significantly attenuated for the much more highly variable heroin than for the relatively reliable crack supply. Perhaps where purity is highly variable, suppliers are more able to get by selling lower-quality products, which are effectively higher priced in pure gram equivalents, and this swamps any tendency for variability in quality to lessen demand.

### **Discussion: why markets for illegal "lemons" survive**

Perhaps the most fundamental question raised by heroin and cocaine markets is how they survive at all in the face of such great uncertainty about product quality and price. Given all the factors that allow for cheating in any individual

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\*For heroin there may be a mechanical element to the relationship between purity and price. It is difficult to handle quantities smaller than 50 milligrams. If the price of heroin is \$1,000 per gram, a "dime bag" (a bag that costs \$10) may contain only 10 milligrams of heroin and thus requires a purity of no less than 20 per cent.

transaction, including imprecise assessment of the quality after consumption, why are there not more frequent “rip-offs”, particularly in a data set such as STRIDE, which is primarily composed of purchases made in the context of new, as opposed to long-standing, customer-supplier relationships? Clearly “rip-offs” are technologically possible. STRIDE contains zero-purity observations, and Simon and Burns even describe sellers who specialize in fraud [26, p. 69]: “They stand where they want, sell what they want, and risk only the rage of their victims or in a rare instance, the ire of a street dealer whose business reputation suffers from proximity”. Likewise, buyers can sometimes “rip off” sellers by stealing the drugs without paying. Why does such behaviour not become so common that it destroys the market, as in the classic problem of the “lemons”?

One hypothesis, oddly enough, is that, even among criminals, trust may be the critical factor. Despite the high rates of turnover, these are markets in which repeat business is the norm and is highly valued.

The following model with plausible parameters illustrates this point. It is assumed that an addict makes twice-daily purchases, say, 600 in the course of a year. It is also assumed that, consistent with Riley [23], the addict has 15 suppliers. The buyer then purchases an average of 40 times annually from each seller. By a simple Bernoulli model, even if there is a one-third probability of each buyer and seller exiting the market in the course of the year (reflecting the cumulative effects of incarceration, ill health and violence from other participants), the probability that this dyad, after making a purchase, will transact again within a year is 0.98.\* In this important respect, illicit drug transactions differ from the classic “lemons” market in which each purchase is the sole transaction involving that seller. This high probability of a “repeated game” may be sufficient to induce cooperation.

In the classic “repeated game” model, when players cooperate the interactions are of uniformly high quality. However, in this case, cooperation does not mean always selling high-quality drugs because the seller has “imperfect” knowledge and, hence, “imperfect” control over quality. Sellers can decide to “rip off” someone, but they cannot simply decide to sell high-quality drugs. It is physically impossible for them to sell drugs with a purity that is higher than that of the drugs they receive from their supplier, and they have at best imperfect knowledge of when that purity is substandard.

Hence, even a cooperating seller provides a wide range of qualities. (Similarly, even a cooperating buyer reports a range of experiences for transactions of a given quality.)\*\* Precisely because the buyer makes so many purchases from the same seller, no single transaction is taken to provide much information about quality or cooperativeness. The seller may aim to provide, in the course of the 10 transactions that occur in a quarter, a distribution of quality and price that is consistent with that in the market in general, but he

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\*(0.98)<sup>40</sup> = 0.446, which is essentially the same as (2/3)(2/3) = 4/9 = 0.444.

\*\*Ethnographers report that complaints are not uncommon and that compensation is sometimes made [37].

or she will have only a very rough estimate of what that distribution is, both because there are no institutions to collect such data and because no buyer or seller can report purity and price per pure gram for a given transaction.

On the other hand, the inevitability of the dispersion in quality affords the seller the opportunity to sometimes cut the drugs a little more. (Similarly, the inevitability of quality dispersion and the seller's "imperfect" knowledge gives customers an opportunity to grumble a little more than is truly justified about poor quality.) So some dispersion is unavoidable, and that dispersion creates incentives and opportunities for occasional further dilution as the drugs move from one stage to the next in the distribution chain;\* however, excessive "cutting" or outright fraud are constrained by the "repeated game" character of the transactions.

Turning this explanation on its head may also help explain another paradox of illicit drug markets. Many buyers purchase small quantities of drugs with great frequency even though there are enormous quantity discounts to be had. For example, the hypothetical addict in this example might make 600 purchases of \$20 each, for a total annual expenditure of \$12,000. Given the typical quantity discounts available [16], the same addict could probably purchase 12 times as much of the drug per transaction for 7 times the cost (for example, weekly purchases of \$140 would yield the same amount of drugs for a total of \$7,000 per year). The usual explanation given for not taking advantage of such opportunities to save 40 per cent is that addicts are cash-constrained and/or cannot be relied on to keep inventory. Both stories are entirely plausible, but a third reason may be that bundling purchases into weekly rather than twice-daily loads erodes the "repeated game" character of the transactions and creates too great an incentive for fraud.

This account of markets surviving despite extreme variability because transactions are "repeated games" is not entirely satisfactory for two reasons. First, the numbers are predicated on an image of retail purchases. Wholesale purchases show similar price dispersion even though transactions are much less frequent. Perhaps, however, the same basic story holds true because it is more expensive to search for alternative transaction partners at higher levels, so customers in high-level transactions may divide their annual number of transactions over a much smaller number of alternative suppliers. Weekly transactions spread over three suppliers still give dyadic relationships a 95 per cent probability of repeat business, even if both customer and seller face the same high risk (probability: one third) of having to exit the market in the course of the year.

The few studies published on high-level dealers (see, for example, Adler [38] and Reuter and Haaga [39]) focus on the number of customers each supplier has rather than on the number of suppliers a customer has, but conversations with experienced investigators suggest that the chains are thin in both directions.

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\*It is easy to tell stories about why one party's preference for immediate rewards over delayed gratification may vary; for example, the customer may be in withdrawal or either party may owe money to someone who is about to employ violence as a collection tactic.

Dealers at the middle or high level may have few potential sources and without the kind of market places available to retailers, they have strong incentives to avoid further search. Relationships are ongoing [20] and repeat transactions are expected.

The second challenge to this model is that not only addicts but also infrequent users and even first-time buyers can purchase drugs. Many first-time and infrequent buyers may purchase from friends, co-workers or others with whom they have an ongoing relationship.\* Such transactions are, for practical purposes, rounds in a repeated game, even though the next round may involve who picks up a restaurant tab or whether one party lends a tool to the other.

Stereotypical anonymous street markets catering to middle-class casual users who (infrequently) drive in from the suburbs in their imported cars are not in fact the norm—depictions in the media notwithstanding—but they do exist. Perhaps anonymous place-based markets only survive where formal organizations (such as gangs) or informal norms (for example, where all sellers are from the neighbourhood and grew up together) enforce quality standards by punishing sellers who defect by offering goods of substandard quality. That is, the reputation for quality may be associated with the place and its norms, not the individuals, and some coordinating mechanism enforces compliance with the norms of that place. The available evidence does not support the view that illicit drug markets in general are highly organized, but it is less difficult to accept the idea that this one special type of market has some such organization, whether formal or informal.

Not all illicit markets have high price dispersion. Illegal numbers banks (common in cities in the north-eastern and mid-western parts of the United States prior to the introduction of state lotteries) had similar pay-out rates, typically 600 to 1 for a three-digit bet; in cities the range was 550-650 to 1. Sports bookmakers also used standard pricing schemes [40]. There may have been unmeasured quality variation in terms of the reliability of large pay-outs\*\* among the banks and bookmakers, but that was surely slight compared with what has been reported here for cocaine and heroin. Neither market was subject to much pressure from law enforcement,\*\*\* and transactions did not have to be particularly hurried.

The high price variability observed in illicit drug markets is thus not just a function of illegality but probably the combination of illegality and a number of

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\*The authors are not aware of data on sources for those who use cocaine and heroin infrequently (as opposed to heavier users, who show up, for example, in criminal justice samples), but in the 2001 National Household Survey on Drug Abuse (now called the National Survey on Drug Use and Health) such questions are asked of cannabis users in the United States. It turns out that 80 per cent of past-year cannabis users most recently acquired their cannabis from a friend and another 9 per cent from a relative (authors' analysis).

\*\*Numbers banks also would offer lower pay-off rates for a few frequently played numbers; there may have been variation among banks in how many numbers were "cut" and how much the pay-off was reduced for those numbers. Fewer than 50 numbers were cut and the reductions might be only 25 per cent; this still left the range of effective pay-out rates constrained.

\*\*\*Arrest was a common experience for numbers sellers, but almost none of them received even brief jail terms [40].

other factors, including the characteristics of those who select into those markets (for example, short planning horizon, situational urgency), the difficulty of ascertaining product quality and law enforcement pressure.

In summary, this paper has documented a number of striking empirical regularities in cocaine and heroin markets, most notably the very substantial dispersion in purity and prices. As is often the case, new empirical information answers some questions but raises others that require further research. Cocaine and heroin markets are obviously a topic of interest to scholars and practitioners in the field of drug policy. They also present interesting opportunities for those who study market problems related to imperfect information and its effects on product quality and price, as well as dispersion in price and quality. The present article represents a first effort to explore these aspects of illicit drug markets.

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