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INSTITUTE FOR DEFENSE ANALYSES

An Empirical Examination of Counterdrug Interdiction Program Effectiveness

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PREFACE

This paper was produced by the Institute for Defense Analyses (IDA) for the Deputy Assistant Secretary of Defense, Drug Enforcement Policy and Support, Department of Defense in response to the task Counterdrug Research on the Effectiveness of Detection, Monitoring, and Interdiction in the Western Hemishpere.

The IDA Technical Review Committee was chaired by Mr. Thomas P. Christie and consisted of the following IDA reviewers: Dr. Arthur Fries, Dr. David R. Graham, Dr. Dale E. Lichtblau, Dr. Bernard H. Paiewonsky, Dr. Paul H. Richanbach, and Dr. Richard H. White. This final version also benefits from comments provided by several qualified reviewers external to IDA.

The authors are indebted to Professor Tyler Cowen, Economics Department, George Mason University, for his review and assistance in identifying and describing several hidden costs caused by interdiction.

AN EMPIRICAL EXAMINATION OF COUNTERDRUG INTERDICTION PROGRAM EFFECTIVENESS

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SUMMARY

This paper presents an analysis of much of the available data relating to the cocaine industry and from that analysis arrives at four primary findings: 1) significant upward excursions in cocaine street prices have occurred in the U.S. since 1983[1]; 2) U.S. interdiction efforts in conjunction with support from the source nations have been the likely cause of these excursions; 3) the price excursions have resulted in measurable reductions in cocaine usage within the U.S.; 4) a strategy of using interdiction external to the U.S. to disrupt cocaine market dynamics and thus raise prices can be a relatively cost-effective approach to reducing cocaine use.

The paper arrives at its conclusions by examining extensive data on the price and purity of cocaine sold in the U.S., as reported by the Drug Enforcement Administration's *System to Retrieve Information from Drug Evidence* (*STRIDE*); operational data from various U.S. and source nation counter-drug agencies; and a variety of indirect or secondary drug-use indicators derived from various sources. These sources of indirect usage indicators include: the Drug Abuse Warning Network (*DAWN*) hospital emergency room data; the Drug Usage Forecast (*DUF*) data derived from drug testing of arrested felons; the Treatment Episode Data Set (*TEDS*) derived from Government treatment centers; and the drug testing program conducted by SmithKline Beecham Clinical Laboratories (SBCL) for civilian and Government organizations.

Nonparametric statistical techniques are used to circumvent serious but poorly understood idiosyncrasies of the *STRIDE* data and to construct a cocaine *street price index*[2] reflecting the intrinsic time variation in cocaine prices within the U.S. market as a whole. This price index reveals that the time history of cocaine prices since 1983 is characterized by a smoothly decreasing trend that abruptly changed in 1989, and on which are superimposed a number of distinct, short duration, price excursions or "bumps." The

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1 "Street price" as used in this paper is not synonomous with "retail price" as commonly used elsewhere.

2 The street price index is defined as the median normalized unit price for the aggregate of the entire *STRIDE* sample. Justification for this definition is presented in Chapter II.

sudden change in the price decay rate and each of the short-term excursions are shown to follow the initiation of major interdiction[3] activities, primarily in the source nations, and are thus to be causally connected. Figure 1 shows the cocaine street price index history since 1983 and the timing of the eight major source-zone interdiction events conducted by the U.S. during that time interval. The open circles are individual price index determinations; the solid line through the data is the result of a smoothing technique applied to mitigate statistical noise.

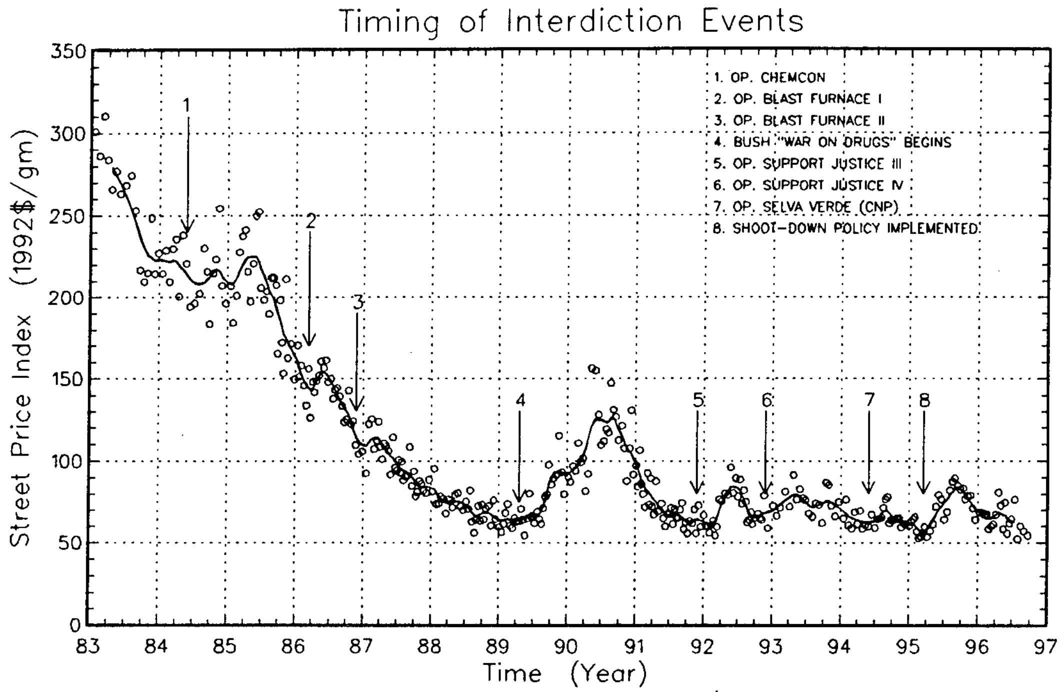

Figure 1. Price history of the U.S. cocaine market with superimposed time markers showing the timing of all major source-zone interdiction events.

The paper then proceeds to show that when cocaine prices have increased noticeably, the four independent drug-use indicators have decreased proportionally, indicating some measure of reduced cocaine consumption. The relation between drug price and drug use is shown to be consistent with the canonical value for the price elasticity of demand (–0.5) commonly used by researchers in the field. Finally, using estimates for total U.S. expenditures in international interdiction and the canonical value for the price-demand elasticity, a rough estimate of cost-effectiveness indicates that the

3 The term "interdiction" used in this paper has a broad scope – those activities exterior to the borders of the U.S. to prevent the production and transport of raw materials and coca products.

cost of decreasing cocaine use by one percent through the use of source zone interdiction efforts is on the order of a few tens of millions of dollars and not on the order of a billion dollars as reported in previous research. The differences are primarily attributed to a failure in the earlier research to account for the major costs imposed on the traffickers by interdiction operations and overestimation of the costs of conducting interdiction operations.

The paper is organized as follows:

Chapter I provides a general background. It identifies the manner in which IDA was tasked to examine interdiction activities, the scope of the tasking, and the manner in which the IDA study team approached that tasking.

Chapter II examines the *STRIDE* data base and presents the methodology used to derive the intrinsic time dependence of prices through the use of an IDA-defined street price index. The nature of the *STRIDE* data base is documented, with a focus on distributional idiosyncrasies that make the use of the customary multi-parameter regression techniques problematic. Justification is provided for aggregating *STRIDE* data at all purchase volumes into a single street price index that characterizes the domestic marketplace.

Chapter III examines several indirect or secondary indicators of drug usage in the U.S. and shows that these are all inversely correlated with the street price index.

Chapter IV examines the time dependence of the street price index and argues that interdiction activities, primarily source-zone actions, have been the likely cause of the excursions and the abrupt change in slope seen in 1989. This chapter further considers whether the excursions in price, attributed to source-zone interdiction actions, result in long-term structural changes in the market, and presents a rough estimate for the cost-effectiveness of interdiction.

Finally, Chapter V addresses the contrast between the cost-effectiveness found in this study and that of a previously published and widely distributed estimate. The differences in the estimates are attributed primarily to five areas of inappropriate assumption or methodology in the previous study.

CHAPTER I

BACKGROUND

I. BACKGROUND

Counterdrug interdiction[1] efforts are routinely grouped into two broad categories, referred to as *source-zone* interdiction and *transit-zone* interdiction. The source zone category refers to activities in the primary coca growing nations, notably Peru and Bolivia, and the transportation lanes from these countries to Colombia, where cocaine sulfate, commonly referred to as "base," is refined into the final product, cocaine hydrochloride, which is marketed in the United States. The transit zone refers to the transportation routes for this final product from South America to the United States. The transit zone includes the Caribbean area, Central America, Mexico, and the adjacent Pacific Ocean area. Along with the Department of Defense (DoD), numerous other agencies routinely play a vital role in the interdiction process, including the U.S. Coast Guard, the Drug Enforcement Administration (DEA), the U.S. Customs Service, intelligence agencies, and the military and police agencies of the source and transit zone nations.

As part of a major shift in U.S. counterdrug objectives, President's Decision Directive 14, issued in 1993, redirected effort and resources from transit-zone to source country interdiction and host nation support. Paradoxically, some policy research results, current at that time, argued that source country control and host nation support were the least cost effective of all drug control strategies. As part of IDA's responsibilities to evaluate U.S. detection, monitoring, and interdiction for our sponsors (the Department of Defense and the U.S. Interdiction Coordinator), new research approaches were initiated to determine the effectiveness of interdiction and methods to improve operations.

At the U.S. Quarterly Joint Staff/U.S. Interdiction Coordinator Interagency Conference in December 1995, IDA was tasked by the U.S. interagency community to examine the relationships between cocaine market price and interdiction activities. Consistent with its operational orientation and experience, the IDA study team adopted an approach of collecting and examining the extensive operational data bases describing actual drug trafficking and usage experience. Such data include known and suspected drug trafficker routings and flight tracks from the source-zone countries through the

1 The term "interdiction" used in this paper has a broad scope – those activities exterior to the borders of the U.S. to prevent the production and transport of raw materials and coca products.

transit zone, drug price and purity data maintained by the DEA, and compilations of statistical data collected by the U.S. Department of Health and Human Services related to drug use (prevalence and consumption).

One of the seminal cocaine data bases is that maintained by the Drug Enforcement Administration as the *System to Retrieve Information from Drug Evidence* (*STRIDE*) program. The *STRIDE* data base (DEA, 1994-1996) includes the quantity, price, purity, and purchase location of actual or negotiated street buys by DEA agents. After applying nonparametric data processing techniques[2] to the *STRIDE* data, the IDA team noted that cocaine street prices since 1980 are characterized by a smoothly decreasing trend on which are superimposed a number of distinct, short duration, upward excursions or "bumps." Furthermore, these perturbations appeared to correspond in time with the initiation of several specific source-zone interdiction activities. This led to IDA's hypothesis that properly focused activities in the source-zone countries aimed at supply disruption can produce significant excursions in the price and purity of cocaine in the U.S.

IDA presented this hypothesis to the interdiction community at the May 1995 Quarterly Interagency Conference. At this time, we strongly urged focused attention on the "air bridge" linking Peru and Colombia as an obvious "weak link" in the industry. At the December 1995 quarterly conference, IDA estimated that the shoot-down policy initiated by Peru in March 1995 and the resulting disruption of the industry should have led to a 30 to 50 percent increase in the cocaine street prices. When the *STRIDE* data for the relevant time period became available (in late December 1995), the estimates were confirmed by analysis of data and were corroborated by independent sources (Krauss, 1995). This result increased IDA's confidence that the correlations observed between source zone events and street price excursions were consistent with a causal relationship.

In January 1996, the U.S. Interdiction Coordinator was briefed regarding this correlation and conveyed a sense of opportunity for capitalizing on this market disruption mechanism. The Interdiction Coordinator indicated his belief that the results were significant and called a special meeting of The Interdiction Committee (TIC) to be briefed on our findings. TIC members recommended that IDA collect the next few months of *STRIDE* data for further confirmation before sponsoring the presentation of these new results to the Office of National Drug Control Policy (ONDCP).

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2 A detailed explanation of the nonparametric techniques used and the rationale for their use, rather than parametric methods, is presented in Chapter II.

At approximately the same time, the DoD office sponsoring this study arranged a staff level discussion with key staff from ONDCP. That discussion raised a question concerning the marketplace linkage between price changes and changes in drug usage. Consequently, IDA examined several data bases that are logically related to drug usage: the SmithKline Beecham Clinical Labs (SBCL) data on random drug testing in the workplace; the Department of Health and Human Services Drug Warning Network (*DAWN*) data base on emergency room treatments; the Treatment Episode Data System (*TEDS*) data base on public drug treatment programs; and the Department of Justice Drug Usage Forecasting (*DUF*) data base from quasi-random testing of arrestees in major cities.

Nonparametric analytical techniques were again employed to extract trend data with the maximum possible time resolution. Applying formal linear regression techniques to binned data produced significant correlations between all of the indirect usage indicators and the *STRIDE* price changes, indicating that cocaine use is responsive to price changes.

This research showed significant effects on street prices directly affecting cocaine usage resulting from several source zone initiatives that had been conducted with relatively modest expenditures. This finding – that source-zone interdiction can be relatively cost-effective – was in direct conflict with the findings of a previously published study entitled "*Controlling Cocaine*" (Rydell and Everingham, 1994), which found source-zone activities to be the least cost-effective of the four cocaine control strategies considered. That study concluded that the most cost-effective of those strategies, treatment of heavy users, was some 23 times more cost-effective in reducing cocaine usage than a source-zone interdiction strategy. Consequently, the sponsor of this research requested that our analytical effort be expanded to identify the cause of the apparent large differences between our findings regarding the effectiveness of source zone interdiction efforts and those presented in *Controlling Cocaine*. Accordingly, IDA undertook a review of *Controlling Cocaine* and its companion report *Modeling the Demand for Cocaine* (Everingham and Rydell, 1994). Our review of these reports identified several assumptions and methodologies that appeared to produce modeled results in disagreement with the actual data.

The above-outlined analyses were documented in a draft IDA document, *An Empirical Examination of Counterdrug Interdiction Program Effectiveness* (Crane, *et al.*, 1996). That document was intended to convey initial findings to those involved in the operational management of the drug interdiction efforts in a timely manner as part of a limited distribution of the quarterly conference proceedings, while encouraging review and comments from other researchers. Subsequently, a number of substantive comments were obtained both from additional reviewers internal to IDA as well as from external reviewers. Reviewers questioned the methodology, assumptions, definitions, and some of the findings themselves.

This paper provides an expanded discussion of the key findings of the draft IDA document and attempts to resolve expressed concerns of methodology, definition, and assumptions. In addition, care is taken to identify explicitly those findings considered to be of primary importance. This paper continues to include judgments and interpretations by the authors with which others may disagree, but by detailing our supporting data, methodology and logic, it is hoped that any remaining disagreements with other researchers in this area may be clarified.

CHAPTER II

THE PRICING STRUCTURE OF THE COCAINE MARKET

II. THE PRICING STRUCTURE OF THE COCAINE MARKET

This chapter develops a suitable statistic from the *STRIDE* data base with which to quantify intrinsic changes in cocaine market prices. This statistic is then used to demonstrate that the commonly assumed *additive* pricing structure for the cocaine market is inconsistent with the empirical evidence. Under the additive model, costs imposed by interdiction upon the production and/or distribution network would have insignificant effect upon the retail price of cocaine. Rather, the empirical evidence indicates that such imposed costs can have a significant effect on the price of cocaine at all subsequent levels of the distribution network. The intrinsic time dependence of cocaine price and purity is presented along with some conceptual hypotheses for why the cocaine market behaves as observed.

A. BACKGROUND

Since the early days of the modern cocaine epidemic (1970s), the prevailing view has been that interdiction efforts have little effect on drug use prevalence or consumption (see: Reuter, Crawford, and Cave, 1988; Cave and Reuter, 1988; Caulkins and Padman, 1993; Riley, 1993). The principal reason for this conclusion appears to be the general belief that the cocaine market is characterized by an "additive" pricing structure. Under the additive model, production and operational price increases at the producer or wholesale level are added on to the retail price of the product. Since production and other import costs are only a small percentage of the final retail price for cocaine, under an additive model, such changes in cost have a negligibly small effect on the final price. The alternative view, which is supported by the available data, suggests a "multiplicative" pricing structure in which cost increases in the earlier levels of the cocaine distribution hierarchy result in significant price effects at all levels of the market.

Reuter and Kleiman (1986) were among the first to model the cocaine market as an additive model. Using the limited data available at that time, they analyzed many plausible price-affecting mechanisms and concluded that "the enforcement-oriented strategy will not work." Since that work was published, the basic conceptual framework has not changed despite the increasing availability of additional market data that has led to increased doubts concerning the validity of the additive model assumption. For example, Caulkins (1993) finds evidence that "lends circumstantial support to the multiplicative model" and concludes that the available data "are not consistent with the additive model." Caulkins further concludes that *if* the multiplicative model is valid for the cocaine market, "then, contrary to conventional wisdom, interventions and policy changes that affect wholesale prices would be expected to significantly affect retail prices." Additional discussion on this point can be found in Boyum (1992).

This study finds that the cocaine market is multiplicative in nature and not additive. Both the quantity of the data analyzed and the analytical techniques used to interpret those data account for the differences between our results and earlier studies. In this work, nonparametric regression techniques are used to extract time dependence, whereas most other researchers have relied on parametric multiple regression techniques or on "standardizing" of individual observations, both of which require explicit assumptions of dependencies, and both of which are error-prone because of the pathological nature of the distributions involved. Although parametric models can correctly account for all dependencies within the data, discovering the correct model, or formulating it from first principles, is problematic. Dealing with the pathologies of the data in a parametric approach is exceedingly difficult.

B. THE *STRIDE* DATA BASE

The *STRIDE* database contains the purchase time, t_i, purchase quantity, Q_i, purchase price, P_i, purchase purity, η_i, and purchase location for approximately 40,000 undercover purchases of cocaine since 1980. (Throughout this paper, the term volume will be used synonymously with "quantity" and all prices have been inflation adjusted to 1992 dollars.) The *STRIDE* purchases range in volumes from 100 milligrams to tens of kilograms.

Some discussion of how accurately the *STRIDE* sample reflects the true market sale volume distribution is warranted. As a first approximation, one might assume that *STRIDE* purchases are a random sampling of the "contracts" available in the market. After all, a DEA agent seeking to make a purchase must go through the same process as any user/dealer looking to make a buy. However, this assumption might be a distorted view. Agents might be targeting larger volume dealers preferentially, which may distort the shape of the true purchase volume distribution. Alternatively, agents might be subject to a "first purchase" surcharge not routinely experienced by the established buyer, thereby biasing the price. Whatever agents are doing, however, has little relevance to the conclusions drawn in this paper. Since this paper focuses upon changes evident in the

STRIDE data, the only requirement is that the *STRIDE* sampling be approximately stationary in time, (i.e., rate of purchase, and the shape of the purchase volume distribution are approximately constant), a characteristic that statistical tests show to be true for *STRIDE* data after 1985. Although some data prior to 1980 exist, the quality of these data is questionable according to the DEA, and we have chosen not to use them. From 1980 to 1985 a systematic bias toward lower volume purchases is clearly evident. This systematic bias makes a direct comparison of absolute price values between widely separated times questionable if pre-1985 data are involved, but on short time scales (a few years) or post-1985, a direct comparison is valid.

Figures II-1a to II-1d show the distribution of *STRIDE* gross (uncorrected for purity) purchase volumes for all purchases from 1980 to mid-1996 in four parts: 0 to 20 grams, 0 to 150 grams, 100 to 600 grams, and 400 to 2,400 grams, respectively. (Figure II-1 is presented in four parts only for ease of publication, visualization, and viewing different scale sizes, and should be considered as a single continuous figure. The overlap of ranges for the four parts is intended to aid the reader in mentally connecting the parts.) The counts in the histograms are per unit purchase volume, i.e., the purchase volume bin sizes vary among the four plots; the number of counts in each bin has been divided by the width of the bin to make the ordinate independent of bin size and allow the four plots to be compared directly to each other.[1]

Within each observed range, the purchase volume distribution is seen to be highly skewed toward low values with characteristic peaks at the preferred market transaction values (e.g., 1/2 oz, 1 oz, 2 oz, ... 1/2 kg, 1 kg). This distribution suggests that the market naturally divides into three groupings – one group at the kilogram level (1/8, 1/4, 1/2, 1, 2, 3 kg, etc.), one group at the ounce level (1/8, 1/4, 1/2, 1, 2, 3, 4 oz) (note: 1 oz = 28 grams), and one group at the gram level – essentially distributed as a hyperbolically or exponentially decaying continuum. A similar division of the market into gram, ounce, and kilogram groupings was adopted by Caulkins (1994) in his examination of *STRIDE* data.

In analyzing the *STRIDE* data, it will be useful to define a unit-price, $U_i = P_i / Q_i$ and two "normalized" quantities: the normalized purchase volume, $(Q_N)_i \equiv \eta_i Q_i$, and the

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1 Because some features of the data are narrower than the bin size, the independence of the ordinate with bin size is only approximate. As a result, the height of a feature in one plot may be slightly different than the same feature in a second plot.

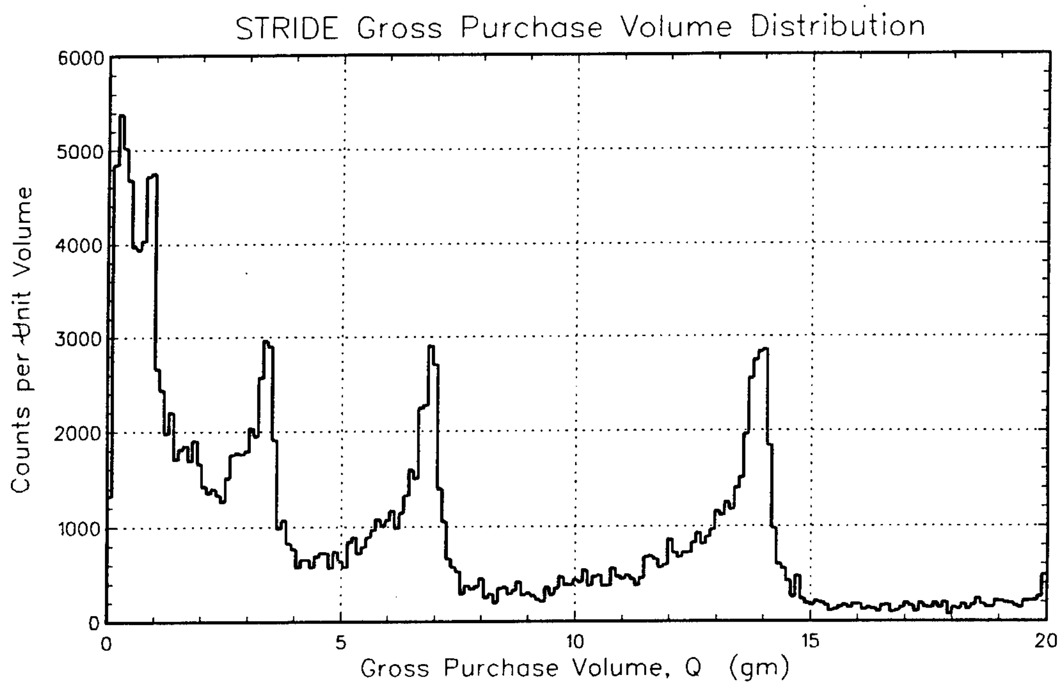

Figure II-1a. Gross purchase volume distribution for all *STRIDE* purchases between 1980 and mid-1996 in the range of 0 to 20 grams.

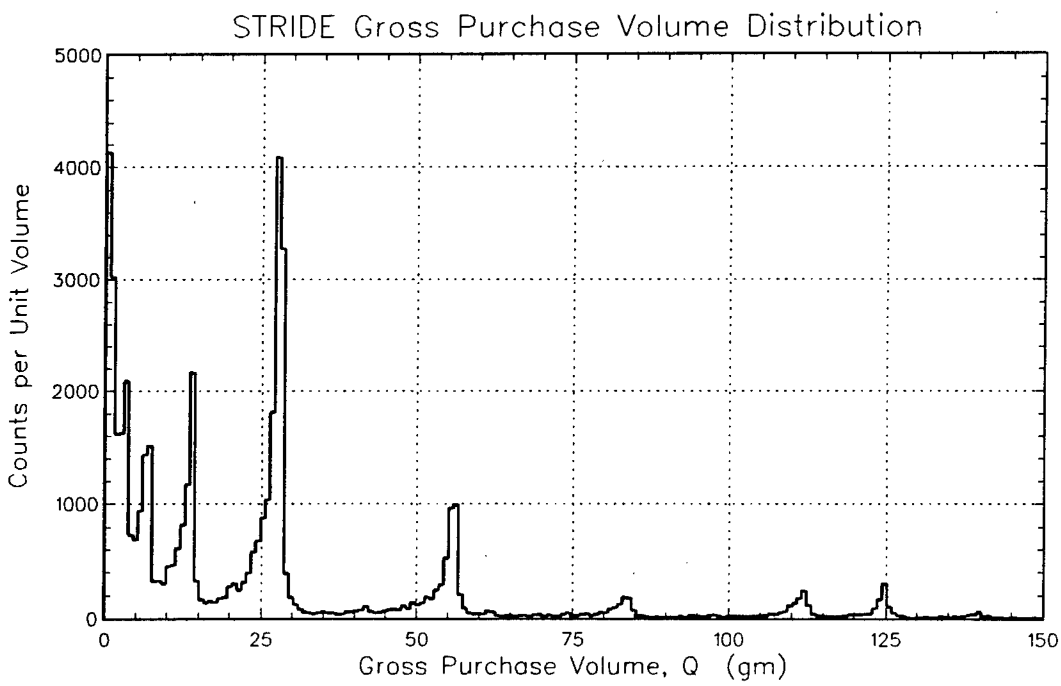

Figure II-1b. Gross purchase volume distribution for all *STRIDE* purchases between 1980 and mid-1996 in the range of 0 to 150 grams.

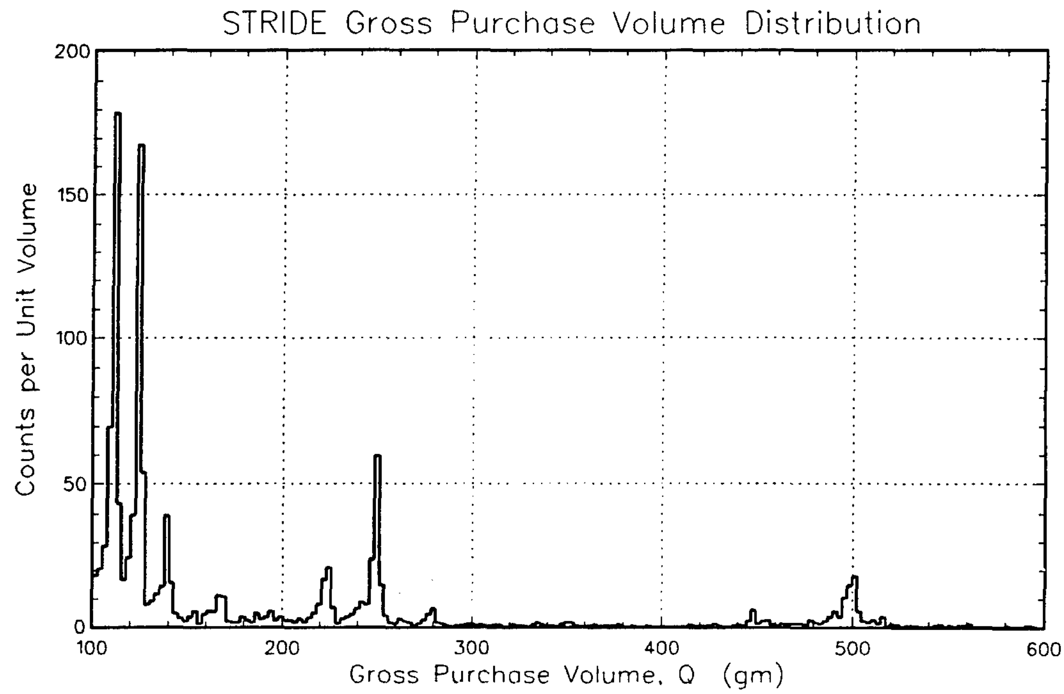

Figure II-1c. Gross purchase volume distribution for all *STRIDE* purchases between 1980 and mid-1996 in the range of 100 to 600 grams.

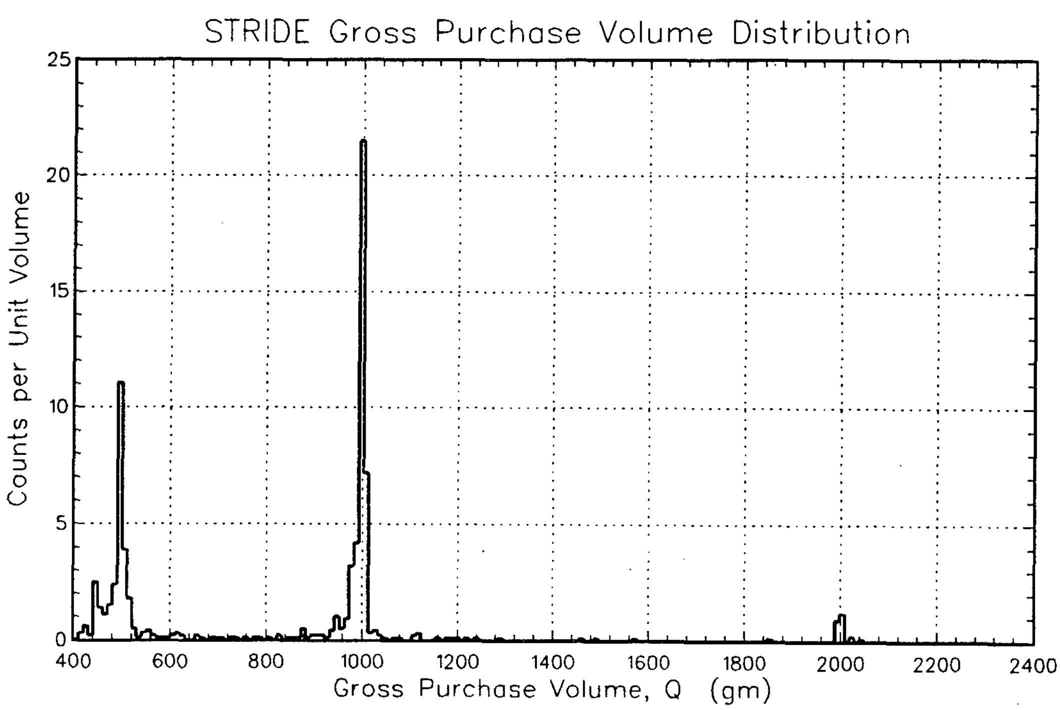

Figure II-1d. Gross purchase volume distribution for all *STRIDE* purchases between 1980 and mid-1996 in the range of 400 to 2,400 grams.

normalized unit-price, $(U_N)_i \equiv P_i/(Q_N)_i$. The distinction between retail, middle, and wholesale levels is quickly lost when one considers only the pure cocaine content of a purchase transaction. For example, Figure II-2 shows the same range of purchase volume distribution as Figure II-1a, but using the "normalized" volume, that is, the purchase volume corrected to 100 percent pure cocaine content. Notice that all the features present in the gross purchase volume distribution have been obliterated in the normalized distribution, leaving only a smooth exponential-like continuum. This is the true market sale volume distribution as sampled by DEA undercover agents.

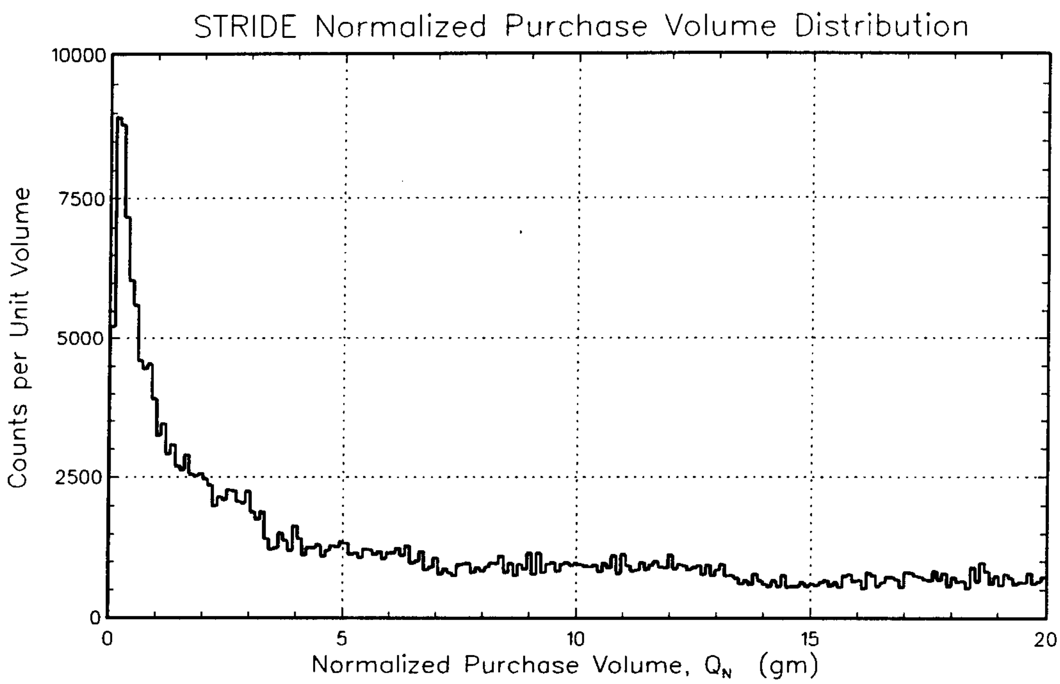

Figure II-2. Distribution of normalized purchase volume for all *STRIDE* purchases between 1980 and mid-1996 in the range 0 to 20 grams.

From the normalized volume distribution shown in Figure II-2, a normalized unit-price distribution can be derived by dividing each actual purchase price by the normalized purchase volume. Figures II-3a to II-3d show normalized purchase price distributions for four purchase volume ranges. Again, all *STRIDE* purchases since 1980 are included. In all histograms, the last bin in the plot contains all counts greater than the plot-limit value. In the upper right-hand corner of each plot are the distribution inclusive volume range and the distribution statistics. All the distributions have very long "tails" that extend further as purchase volumes get smaller (e.g., notice the difference between the mean and the median for each distribution).

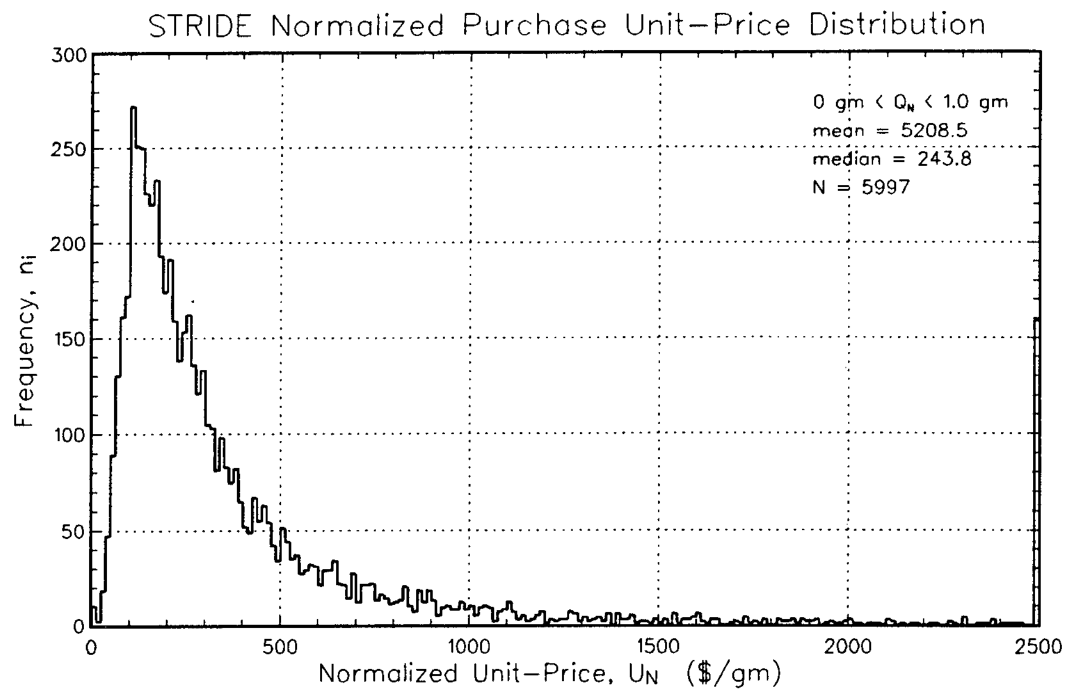

Figure II-3a. Normalized unit price distribution for all *STRIDE* purchases between 1980 and mid-1996 within the normalized purchase volume range of 0 gm to 1.0 gm. The rightmost bin contains all values greater than $2,500 per gram.

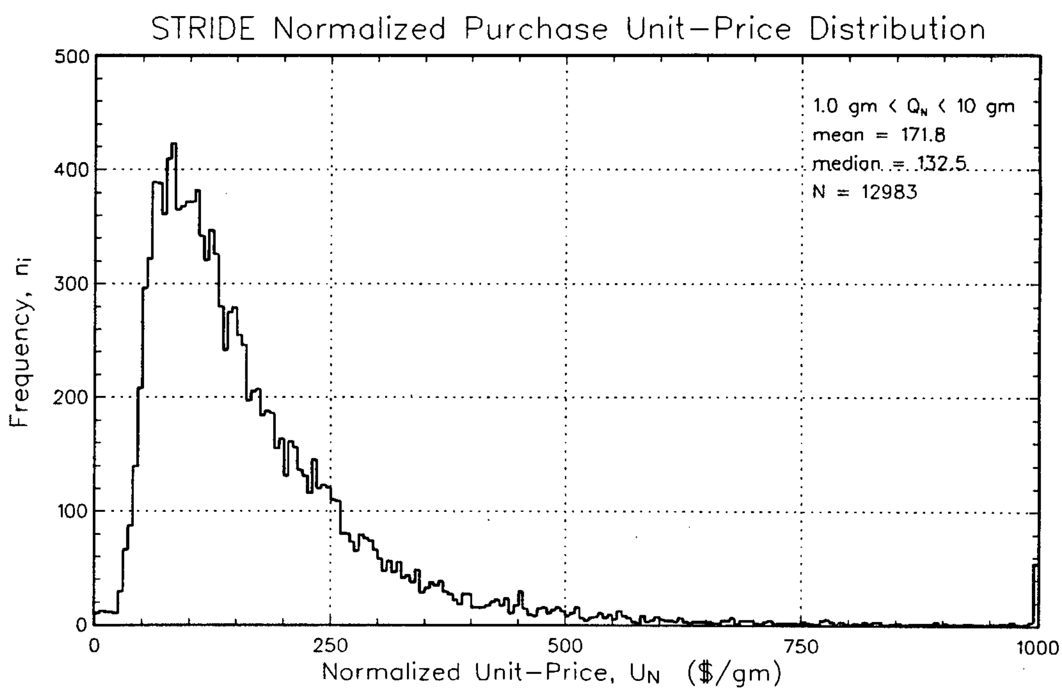

Figure II-3b. Normalized unit price distribution for all *STRIDE* purchases between 1980 and mid-1996 within the normalized purchase volume range of 1.0 gm to 10 gm. The rightmost bin contains all values greater than $1,000 per gram.

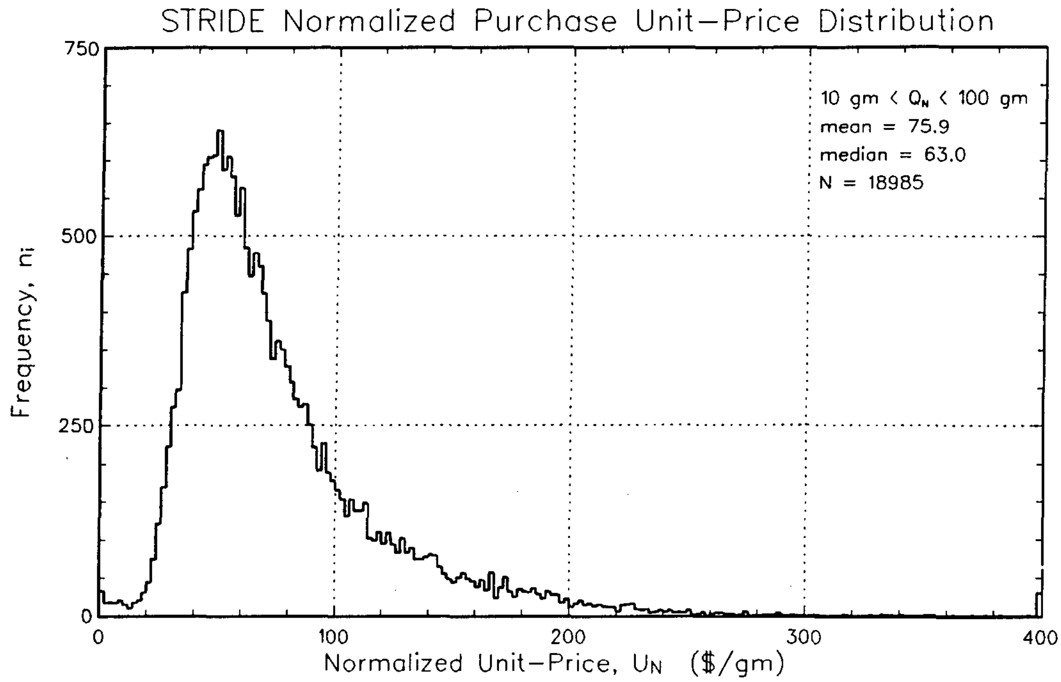

Figure II-3c. Normalized unit price distribution for all *STRIDE* purchases between 1980 and mid-1996 within the normalized purchase volume range of 10 gm to 100 gm. The rightmost bin contains all values greater than $400 per gram.

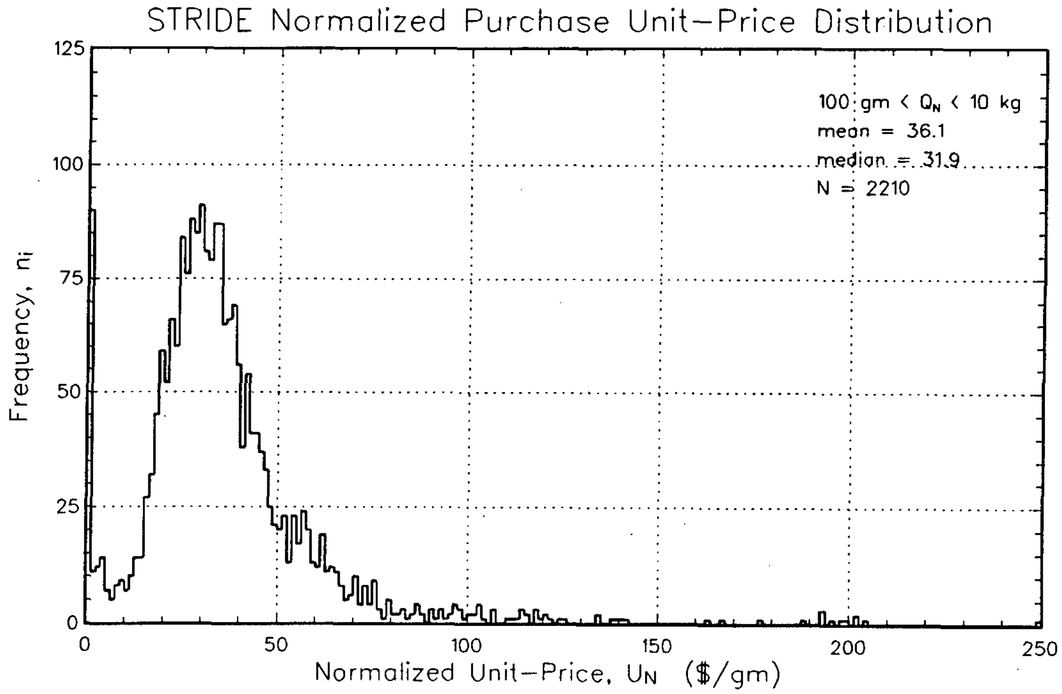

Figure II-3d. Normalized unit price distribution for all *STRIDE* purchases between 1980 and mid-1996 within the normalized purchase volume range of 100 gm to 10 kg. The rightmost bin contains all values greater than $250 per gram.

The distribution of Figure II-3d is bimodal with a distinct component below \$10 per gram. These purchases may reflect contracts made at the import price by DEA agents dealing directly with importers or may reflect some other idiosyncrasy of the data. Regardless of the origin of these low-priced purchases, they constitute a small fraction of the total and do not affect the median values, used exclusively in this study, and therefore do not greatly affect any statistical outcome.

In all cases, the long tail of the unit-price distribution is due partly to a strong dependence between unit-price and purchase volume (the bigger the buy, the lower the unit-price), but a long tail is also an intrinsic property of the unit price distribution, even for narrowly restricted volume ranges. This tail arises because cocaine is almost always adulterated, thus making the unit price of the actual cocaine content for any individual purchase essentially a random variable. Since the degree of adulteration is strongly dependent on the purchase volume, with larger volume purchases being observed to be much purer and having smaller variances than smaller purchase volumes, a larger purchase volume means a smaller variance.

The long tails of the normalized purchase unit price distributions obey the so-called Pareto-Levy law in economics (Mandelbrot, 1983, and references therein). The tails illustrate essentially asymptotic behavior in which the cumulative distribution function, for large values of the independent variable, converges to an inverse power-law. If the logarithmic slope of the power-law is shallower than −1.0, then the first and second moments of the distribution diverge for an infinite sampling and are random noise for any finite sampling. If the logarithmic slope is between −1.0 and −2.0, the first moment converges, but the higher ones do not. It is the existence of these Pareto-Levy tails in the price distributions that makes analysis of these data problematic.

Figure II-4 shows explicitly the Pareto-Levy tails of the normalized unit-price distributions for three of the four ranges of normalized purchase volume shown in Figure II-3. The graph shows the probability of paying more than x dollars per gram as a function of x. Notice that, for the 0 to 1 gram sales, the slope of the tail of the probability curve is very close to −1.0; therefore, not only are the higher moments of this distribution divergent, but so is the mean. The main consequence of this is that the mean price of cocaine for purchases in the volume range of 0 to 1 gram is dominated by random noise. This result calls into question all analytical studies that monitor prices by computing quarterly (or longer) averages predominantly in the range of 0 to 1 gram. In addition,

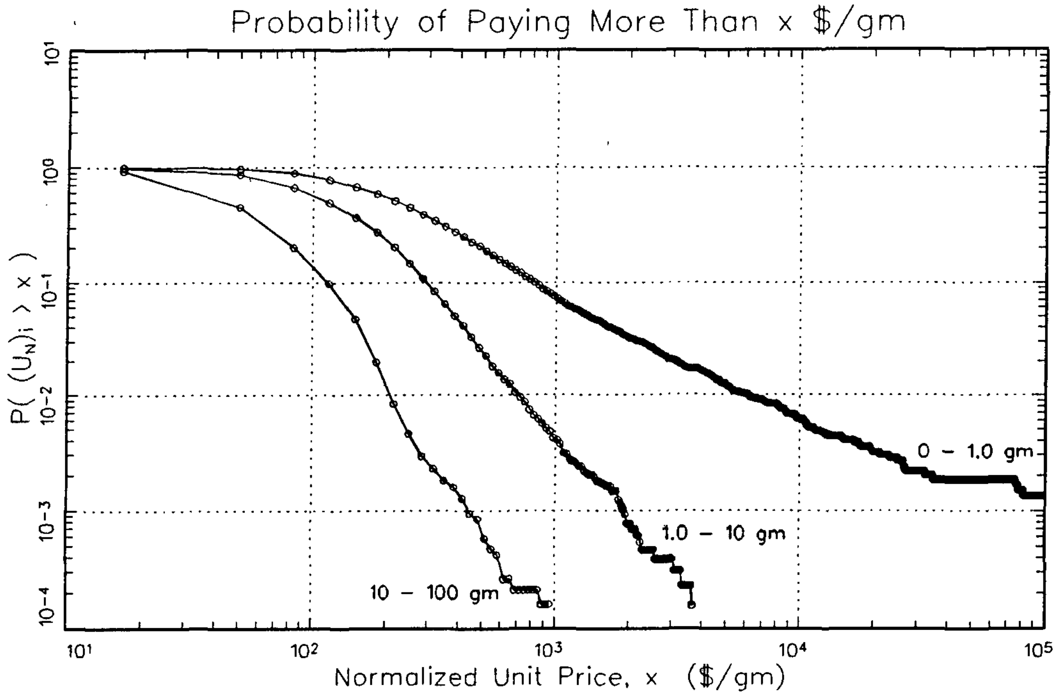

Figure II-4. Probability of paying more than x $/gm when purchasing cocaine on the street as determined from the *STRIDE* data base for three ranges in purchase volume.

because the slopes of the distribution tails are shallower than −2 for a large portion (in particular the "retail" regions) of the *STRIDE* data, it also raises serious questions about the validity of the ubiquitous multiple linear regression techniques that have been used to extract price time dependencies or price-demand elasticities, since the methodology underlying such techniques is predicated on the existence of finite variances.

C. EMPIRICAL EVIDENCE FOR A MULTIPLICATIVE COCAINE MARKET

In order to quantify market dynamics, it is necessary to extract the time dependence of price and purity from the time series, that is, construct some statistic to reflect intrinsic price and purity as a function of time. Before constructing such a statistic, it is instructive to look at the time dependence of prices for narrow ranges in purchase volume.

Because of the difficulties raised by the long Pareto-Levy tails of the unit-price distributions, it is necessary to select a statistic insensitive to the tails with which to form a time dependent function. Statistical principles indicate the use of the median value, rather than the mean, since the robustness of this statistic is well documented. Figure II-5 shows a plot of the median normalized unit-price for three purchase volume intervals of the *STRIDE* data between January 1983 and June 1996.[2] The data have been "cut" into these three purchase volume intervals to reflect the three notional market levels: retail (0-10 gram), middle (10-30 gram), and wholesale (> 30 gram), although, as previously pointed out, such a distinction is, in our opinion, somewhat arbitrary.

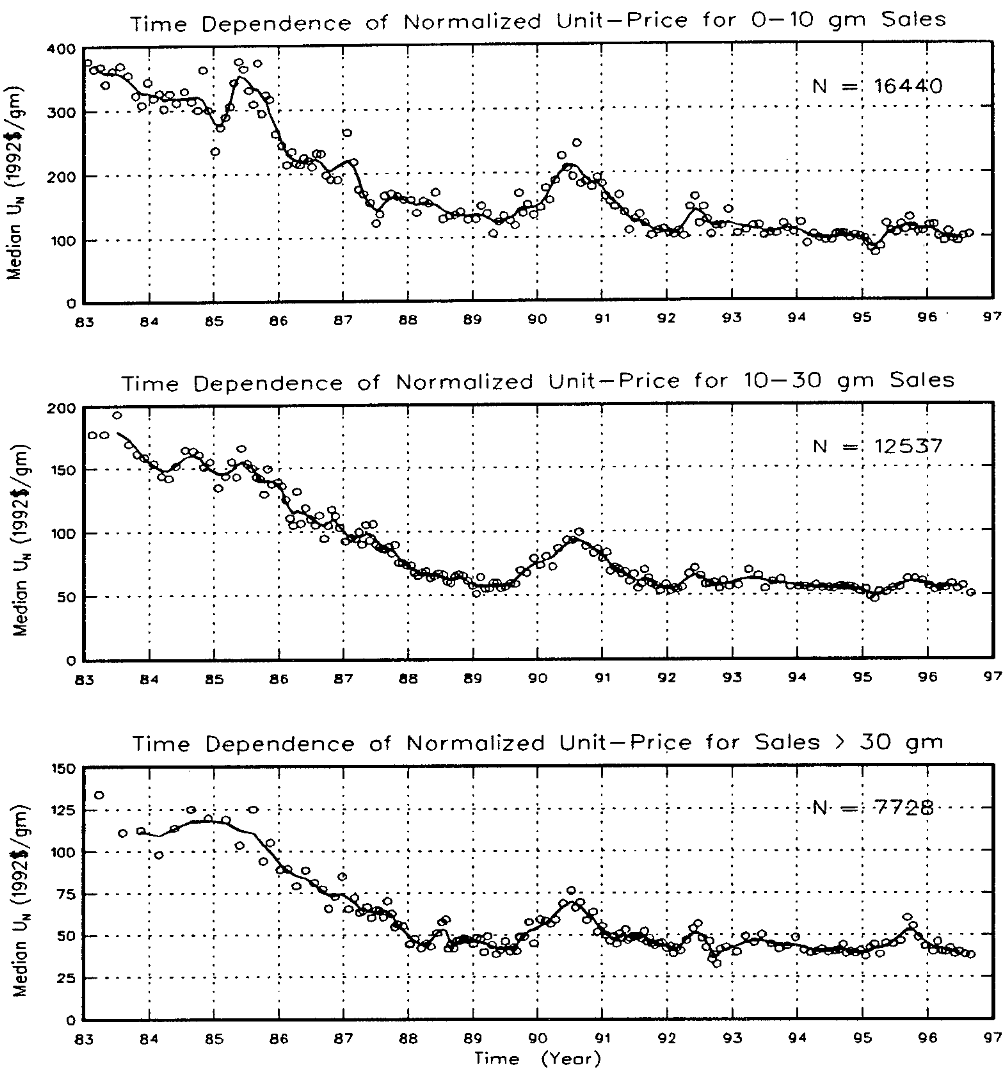

Figure II-5. Median normalized unit prices for cocaine for three market distribution levels. Top: 0 to 10 grams; middle: 10 to 30 grams; bottom: 30 grams and larger. The values of *N* in each panel is the number of *STRIDE* purchases contained in each grouping.

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2 In this figure and in the following figures of time dependencies, the starting year is selected as 1983 rather than 1980 because inclusion of 1980-1983 data greatly compresses the scale of the plot without adding significant information.

In this figure, and in all time sequences to follow, each open circle represents the median value of L individual transactions that have been sorted to be consecutive in time and within the appropriate volume range. The solid line running through the data points is the result of a nonparametric regression technique, closely related to the well-known median filtering approach (see: Mosteller and Tukey, 1977). The line is generated by convolving the median data points with a triangular function, whose width is typically a few months, to smooth out noise fluctuations. The procedure is essentially a weighting scheme that replaces the jth data point by a weighted sum of K nearest neighbors (bidirectionally) with the weights assigned in direct proportion to the time separation between the data point and the neighbors. Since this approach is used repeatedly throughout this paper, the procedure is explicitly described below.

Starting from the individual *STRIDE* purchase samples, the normalized unit price of each transaction is computed.

$$(U_N)_i \equiv P_i / (Q_i \eta_i).$$

The data are then sorted in time (t_i) to form a time series, sectored into groups of L samples each, and for each sector, a group median value is computed to define the median normalized unit price, $Z(t_j)$, for the data index interval $(j-1)L < i < jL$

$$Z(t_j) = \underset{i=(j-1)L}{\overset{jL}{X_{50}}} [(U_N)_i]$$

where X_{50} is a notation for the median operator. The time t_j to which the median value Z is assigned is the median of the times t_i over the interval. The "regression" function curve is then given by the convolution

$$F(t_j) = \sum_{k=-K/2}^{+K/2} Z(t_{j+k})\, W(t_k)$$

where $W(t_k)$ is a symmetric triangular weighting function with zero mean and unity integral. The width of the base of this function (smoothing time interval) is set by the value of K. Note that none of the conclusions of this paper depend on the regression curves derived by the above procedure. The regression curves are included solely to enhance the exposition and help in visualization of the time dependence of the noisy data.

For the solid lines in Figure II-5, the values of L and K have been set to $L = 100$ and $K = 8$. Notice that the three time-dependent curves in the figure are statistically similar, that is, they all go up and down in direct proportion to each other. Slicing the data into other purchase volume intervals always produces similar results, indicating that the systematic local maxima and minima in the curves are not the result of sampling fluctuations, but the result of intrinsic variations in time that affect all prices at various stages of distribution simultaneously and proportionally to each other. This constitutes the primary evidence supporting the conclusion of a multiplicative market.

The finding that the empirical evidence is consistent with a multiplicative model for the cocaine pricing at all levels of the domestic market – and inconsistent with an additive pricing model – argues that costs imposed at an early level of the cocaine production and distribution network, e.g., as a result of interdiction activities, can produce much larger increases in the retail price of cocaine than customarily has been recognized.

D. THEORETICAL FOUNDATION FOR A MULTIPLICATIVE MARKET

The argument that the effects of interdiction can yield significant increases in the retail price of cocaine receives support from several quarters. We first show that significant movements in the street price of cocaine are consistent with standard economic theory, and then discuss some other factors that may be special to the cocaine market and that may amplify such price movements, even beyond what standard theory would suggest.

Advocates of the additive pricing model typically argue that increased costs imposed upon cocaine production or distribution by interdiction activities can produce only (negligibly) small changes in the retail price of cocaine. The argument runs as follows: the production costs for 1 gram of cocaine typically run a few dollars, whereas the retail price is much higher, typically $100 to $200. A doubling of production cost, say from $2/gm to $4/gm, therefore will affect the retail price only slightly, according to this view, since the added $2/gram is only a small fraction of final market price.

This example poses a misleading dilemma for an economic analysis of interdiction. Interdiction typically creates non-linear effects on costs. In other words, it is incorrect to claim that marginal cost has risen a constant percentage across the entire range of the cost curve. For some units, the marginal cost of production does not change at all. For other units, the marginal cost of production becomes extremely high, perhaps infinite, at least in the short run. Such non-linear effects are easy to see in the costs associated with laboratory destruction, air interdiction, or spraying. Much of the market is not affected, while other parts of the market are affected significantly. These effects create a sharp upward break in the cost curve beyond a certain range.

The additive model assumes that interdiction acts simply to raise the costs of cocaine coming into the U.S. But in addition to raising costs, interdiction also limits the flow of cocaine supplies into the U.S. The nonlinear effects on supply is illustrated in Figure II-6, where interdiction shifts the supply curve from S to S'. Because the demand for cocaine is relatively inelastic, such a reduction in the flow of supply may significantly increase the short-run market-clearing price from P to P'. This is the same kind of price spike that is often observed in other markets when the flow of supplies is disrupted, and we believe this effect explains the significant price excursions observed in the data. In the long-run, cocaine suppliers will adapt to market disruptions by adopting alternative distribution channels, but they likely will not be able to bring costs down to the original supply curve S, and there may continue to be supply-limiting effects even in the long-run. Because the additive model overlooks these supply-limiting effects of interdiction, it defines away a potent effect on cocaine pricing and usage.

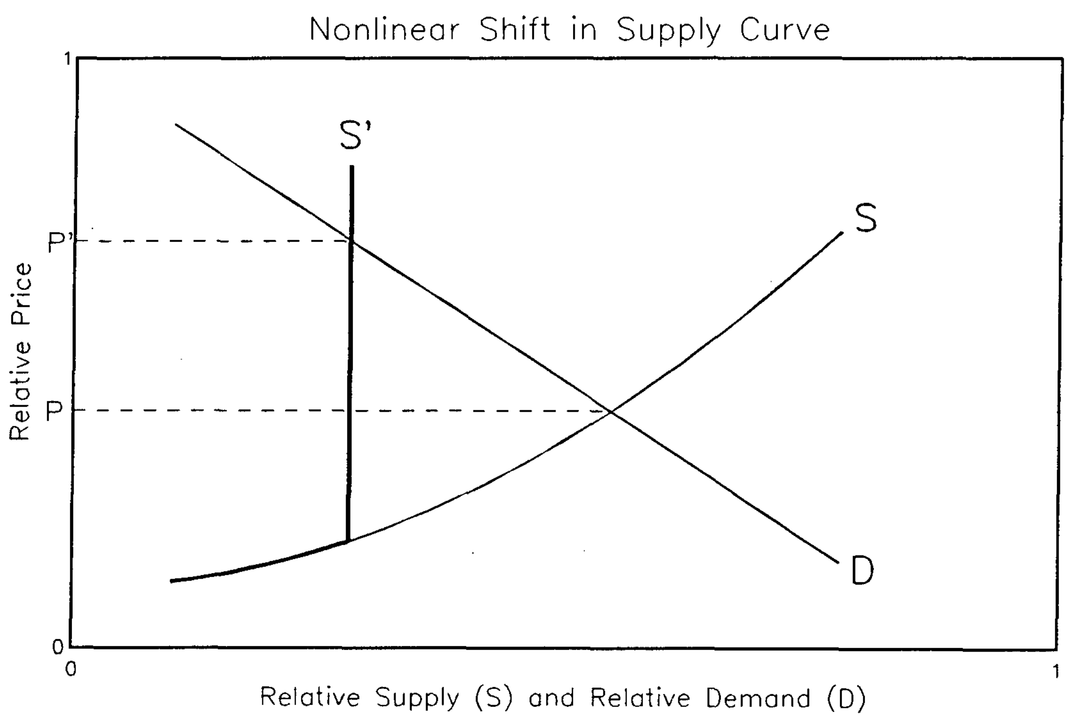

Figure II-6. Supply and demand curves illustrating the nonlinear behavior resulting from supply interdiction.

As noted in the previous section, we have observed a consistent multiplicative pricing relationship in the domestic cocaine distribution system. This has persisted over wide variations in prices, suggesting that the relationship is deeply ingrained in the cocaine distribution culture. It may also reflect accepted distribution cost relationships. In an illegal market such as this, the costs of the raw materials are small compared with the costs associated with security, prosecution risk premiums, and other distribution costs at the various tiers in the distribution system. At the small volume retail level, the costs of security and the higher risks of arrest may be the dominant costs of business. The stability of pricing relationships over time is consistent with a product having a low elasticity of demand, and with a rigidly established marketing hierarchy. The economics of the structure and pricing within the cocaine distribution system is worthy of further study.

Specifically, cocaine sale and distribution may be characterized by self-similar hierarchical, or "fractal," structures. We offer the following remarks as an interesting lead for future research, but emphasize that our basic conclusions do not depend upon the acceptance or rejection of specific propositions about fractal market structure.

A fractal structure results when, at every level of the distribution chain, dealers buy in quantity Q and resell in lots of quantity Q/M while applying a price markup of S. If M and S are constant throughout the market, then the distribution chain is self-similar and a fractal structure results. The parameter M is called the multiplicity or branching ratio and the parameter S, the markup or price multiplier.

The analysis of fractal market structure is consistent with the standard framework of tax incidence theory. If a product has many stages of production and distribution, fractal results will emerge if a given percentage increase in cost has a more than proportional increase on price at each production stage (on how prices respond to increases in cost, see Atkinson and Stiglitz 1980, especially Lecture 7). Assume, for instance, that a given percent increase in cost at the level of coca leaf production creates a 10 percent increase in the price of leaves. This implies a 10 percent increase in cost for the next level of production, which in turn can increase the price of that stage's outputs more than 10 percent. If the outputs of that stage rise in price by 20 percent, then the next stage experiences a cost increase of 20 percent, and so on. The cost increase at each stage increases the price of the inputs purchased by subsequent stages of production, and can have a *multiplicative* effect on final market price, hence the name "multiplicative market structure." The fractal concept refers to the ability of the price change to propagate itself and expand through successive stages of production. Such a market structure requires that the gross purchase price, P, as a function of transaction size, Q, satisfy the following relation:

$$M\,P(Q/M) = S\,P(Q).$$

This implies a market in which volume discounts (unit-price —volume relation) are related by a power-law

$$U(Q) \propto Q^{\gamma},$$

where $U(Q) = P(Q)/Q$. The exponent, γ, in this relation is related to M and S by the fundamental fractal relation:

$$\gamma = -\log(S)/\log(M).$$

Such an inverse power-law relation between unit purchase price and purchase volume is indeed observed within the *STRIDE* data. This relation is valid for both the normalized and gross quantities and is fundamental to this market. Figure II-6 presents, on a log-log scale, a plot of the median normalized purchase price from the *STRIDE* data base versus the normalized purchased quantity (volume). Each point on Figure II-7 represents the median of the normalized unit-prices of 100 transactions in the same normalized volume bin. (For purchase volumes greater than 1,000 grams, each data point represents the median of only 10 transactions.) The straight-line relationship between log price and log quantity in the figure has a slope of −1/3 and spans about four orders of magnitude in purchase volume. This power-law relationship is consistent with a self-similar hierarchical distribution network model and is direct evidence for a fractal structure of the cocaine market and the multiplicative nature of its pricing scheme.

Such a self-similar hierarchical market model was proposed by Caulkins and Padman (1993). Although their model is not couched in the language of fractals, it does contain all the necessary elements. A very similar fractal market structure may exist in the heroin industry (although the *STRIDE* heroin data have not been yet examined). Moore (1970), building on work by Preble and Casey (1967) who used information obtained from dealers and users, outlines a near-hierarchical distribution chain for heroin with six levels. With minor modifications, the system outlined by Moore can be transformed into a fractal scheme with multiplicity $M \approx 10$ and mark-up $S \approx 3$.

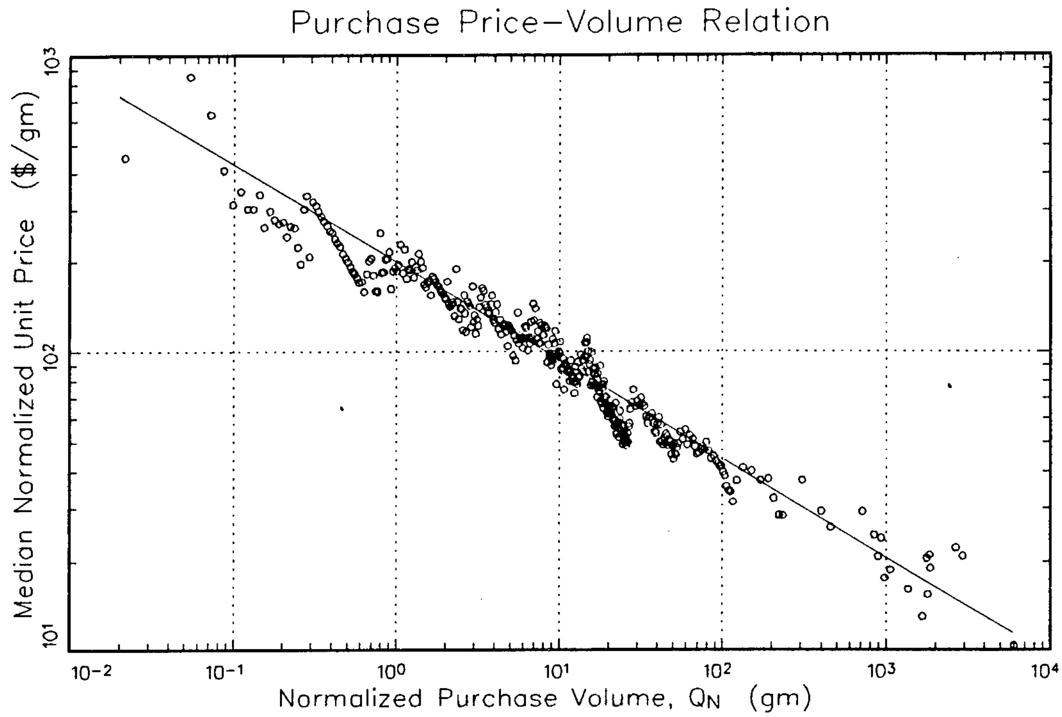

Figure II-7. Median normalized unit price versus normalized purchase volume for all *STRIDE* data between 1980 and mid-1996. The solid line through the data is $Y = 200\ X^{-1/3}$.

While a fractal structure may not be commonplace for normal, i.e., legal markets, it is conceptually reasonable for an illegal market in which risk is the dominant force mitigating profits. The risks to a dealer of being arrested or exposed to violence increase as the multiplicity or branching ratio, M, increases, thereby providing an incentive to hold down the number of customers, while profits, because of the inverse power-law between unit-price and volume, increase rapidly as the multiplicity increases. Aggregating the data into time intervals quickly shows that the exponent of the price-volume relation has been constant since 1980, indicating that the interplay between risk and profit has not changed significantly since that time.

The observed value of the exponent of the price-volume relation from the *STRIDE* data (Figure II-6) is approximately $\gamma = -1/3$. The discussion in Section B suggested that the street market naturally divides into three groupings at the kilogram, ounce, and gram levels, respectively, thus revealing a preference for a multiplicity of approximately 30. With an exponent $\gamma = -1/3$, and $M = 30$, one calculates a price mark-up of about $S = 3$.

The interpretation and consequences of this fractal market structure are profound. They imply a market that is multiplicative in price structure and that the product is sold through a distribution network that is self-similar and hierarchical; that is, every dealer takes approximately the same risk and makes approximately the same return on investment. We are aware of no fractal markets other than this one, although fractal structures are common in socio-economic systems (see: Mandelbrot, 1983, for a discussion and references).

With the postulation of this fractal market structure, it is possible to construct a reasonable outline of the market hierarchy in the United States. Consider the following first-order estimate. Approximately 200 high-level dealers purchase lots of approximately 30 kilograms at an import price of approximately $7 per gram. These 200 dealers sell in lots of 1 kilogram to 6,000 individuals at a unit price of about $20 per gram. These dealers in turn sell in lots of 1 ounce (30 grams) to 180,000 individuals at $60 per gram, who in turn sell in lots of 1 gram, at a unit price of $180 per gram, to 5.4 million end users. The schematic below may help to visualize the hierarchy:

$$30\text{ kg @ } 7\text{ \$/gm} \Rightarrow 200 \Rightarrow 1\text{ kg @ } 20\text{ \$/gm}$$

$$1\text{ kg @ } 20\text{ \$/gm} \Rightarrow 6{,}000 \Rightarrow 1\text{ oz @ } 60\text{ \$/gm}$$

$$1\text{ oz @ } 60\text{ \$/gm} \Rightarrow 180{,}000 \Rightarrow 1\text{ gm @ } 180\text{ \$/gm}$$

$$1\text{ gm @ } 180\text{ \$/gm} \Rightarrow 5{,}400{,}000.$$

This schematic is not meant to be interpreted in detail. In reality, all of the numbers are approximate, and, furthermore, they do not represent single values but the integrals of distributions that may be near-normally distributed or highly skewed. In order for the above scheme to account for a total consumption of 250 to 300 metric tons of cocaine per year, the hierarchy sequence must be repeated an average of once per week.

E. EXTRACTING INTRINSIC TIME DEPENDENCE IN PRICE AND PURITY

For any range of purchase volume, a time-dependent function using the median of the price distribution values can be formed. However, when the volume range is narrow, there are few data points available and the function is dominated by statistical fluctuations. To decrease the statistical noise, we use the observation that unit prices at all levels of the market (all purchase volumes) are proportional to each other and that the variances are very large. This allows the aggregation of all purchases, irrespective of purchase volume, to define a price index that reflects a price characteristic of the market as a whole without distinction to wholesale, middle, or retail levels. Such an approach may appear to be questionable since there are wide differences between high-level prices and low-level prices. However, because all prices are proportional and have very large dispersions, the composite median is itself proportional to all other prices, and thus, with greatly decreased statistical noise, this composite median does an excellent job of resolving temporal changes related to interdiction operations.

With the above justification, we therefore define a cocaine *street price index* as the *median normalized unit price* for the aggregate of the entire *STRIDE* sample (all purchase volumes), as:

$$\mathrm{SPI}(t_j) = \underset{i=(j-1)L}{\overset{jL}{X_{50}}}[\,(U_N)_i]$$

typically with L = 100, but any reasonable binning size will yield similar results. Since source zone interdiction operations generally affect the U.S. market as a whole, all purchase locations are aggregated together. (Individual locations could be segregated at the cost of greatly increased statistical noise.) Note that the "street price" as measured by this index is not synonymous with the "retail price" often used in the literature, since the retail price normally refers to only the smallest volume transactions available on the street.

This street price index represents the unit price per pure gram of cocaine for the median purchase volume of the entire *STRIDE* sample; we interpret this index as characteristic of the cocaine market as a whole. In computing this index, care was taken to ensure that no major changes in the purchase volume distribution have occurred over the period of interest. As previously noted, because there is some systematic change in the *STRIDE* purchase volume distribution before 1985, absolute values of this index cannot be compared between two widely separated times if data prior to 1985 are included. Over the short time-scale prior to 1985, or post-1985, however, the index is well-behaved and any systematic trends can be interpreted as real excursions. The great advantage of this procedure, of course, is that it uses all the data points to compute a single characteristic price of the market as a whole, while minimizing statistical fluctuations and enhancing the time resolution of the available data.

We turn now to the goal of the long discussion above – the intrinsic time dependence of cocaine price and purity. Figure II-8 shows the street price index (in constant 1992 dollars) as a function of time, and Figure II-9 shows the corresponding median purity. In both plots, L, the number of data points over which the medians are computed, has been set to 100 and the smoothing function width at K = 8. The two figures

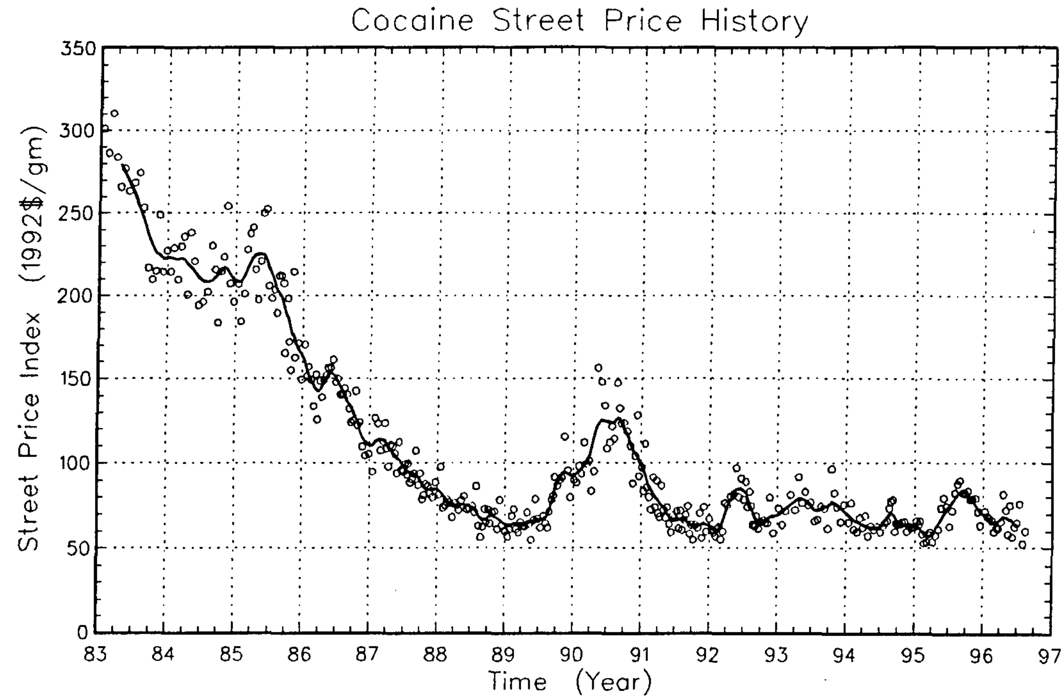

Figure II-8. Price history of the cocaine market as defined by the street price index.

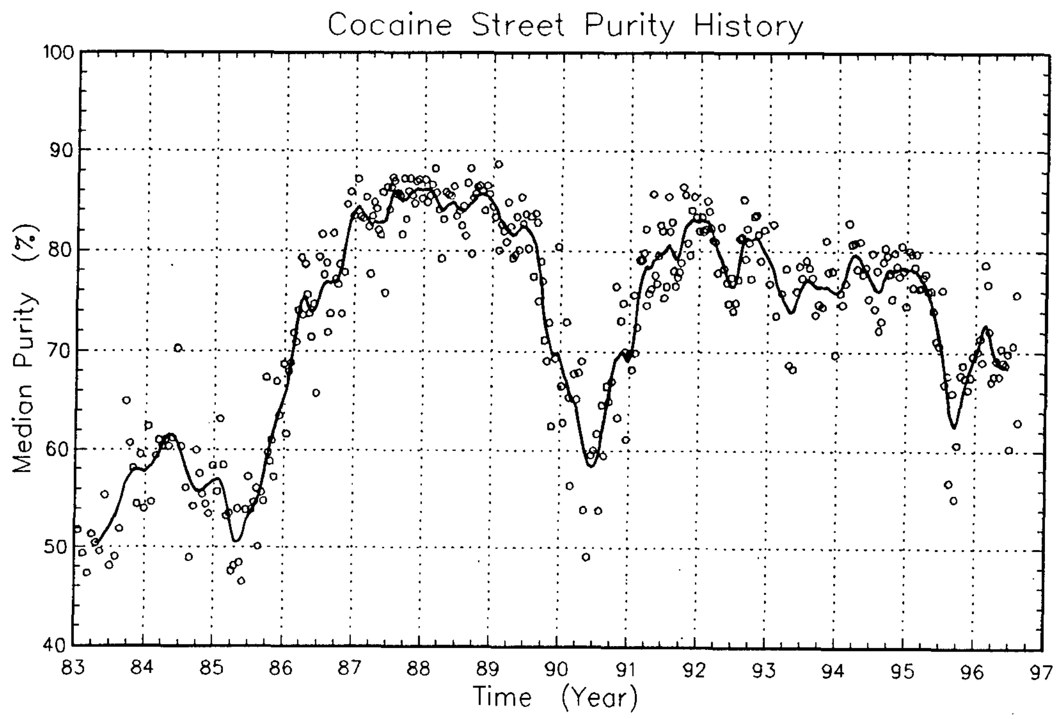

Figure II-9. Purity history of the cocaine market as defined by the median purity of the *STRIDE* sample.

show a complete history of the cocaine market since 1983. With the exception of a few prominent features, the plots show that cocaine prices have been in a general decline since 1983 while cocaine purity was on the rise prior to 1988 and has been in slow decline since. It should be understood that the "control" parameter in this market is purity. When the market supply is obstructed, the market compensates by lowering purity, which effectively increases price. Although during shortages the gross unit prices do increase somewhat, the bulk of the price-raising mechanism is through a lowered purity.

Figure II-8 reveals that the price of cocaine, as reflected by the street price index, can be characterized as a smoothly decreasing trend on which are superimposed a number of distinct, but short duration, upward excursions or "bumps," which in all cases recover to the original trend line. The following chapter presents evidence showing that associated with these price excursions is a noticeable decrease in cocaine use. Chapter IV discusses the probable causes for the price excursions.

CHAPTER III

THE RELATIONSHIP BETWEEN COCAINE PRICE AND USAGE

III. THE RELATIONSHIP BETWEEN COCAINE PRICE AND USAGE

If one believes that the price excursions observed in the *STRIDE*-derived street price index reflect meaningful changes in the price of cocaine as available on the streets of the U.S., one would expect that these price excursions would cause some change in usage patterns, since few would argue that the demand for cocaine has zero elasticity to price. This chapter examines several indirect measures that are logically related to cocaine use in an attempt to confirm that the price excursions noted in the *STRIDE*-derived street price index do, indeed, reflect meaningful changes in the use of cocaine in the U.S.

There are two parameters relating to use: *prevalence* and *total consumption*. Prevalence addresses the number of persons using the drug, while consumption addresses the total quantity of drug consumed by those users. These parameters are related through the shape of a differential distribution function of consumption, what may be termed the "usage distribution function" or, for brevity, the "user function." The user function, $n(c)$, represents the number (n) of cocaine users that use c grams of cocaine per year in some narrow range about c. Prevalence is defined as an integral of $n(c)$ between any two limits of c, and total consumption as the integral of c times $n(c)$ between any two limits. The shape of the user function as derived from the National Household Survey on Drug Abuse (NHSDA 1992) data is approximately hyperbolic

$$n(c) \propto c^{-1}$$

with sharp cut-offs in the vicinity of $c = 0.1$ gm/yr (one dose per year) and $c = 500$ gm/yr (a reasonable physiological limit).

Because of the hyperbolic behavior of the user function, prevalence is dominated by the low-consumption end of the distribution and total consumption by the high end. In general, any price-induced change in demand depends on where on the user function curve the change operates. A large decrease in the prevalence of low consumption users has little effect on overall consumption, while a small change in heavy use prevalence has a large effect on total consumption but little effect on total prevalence. Since the four indirect usage indicators described below reflect different portions of the user curve, it would not be surprising to find that the response to a price change may be different for the four indicators described.

The indirect indicators of usage investigated are:

1. The number of emergency room admittances linked to cocaine at participating hospitals in the *Drug Abuse Warning Network* (*DAWN*) data collection program.
2. The positive test rate for cocaine in the Department of Justice *Drug Usage Forecasting* (*DUF*) program. This program conducts semi-random drug testing on several hundreds of arrestees in 23 major cities every calendar quarter.
3. The positive test rate for cocaine in the testing program conducted by the SmithKline Beecham Clinical Laboratories (SBCL). Typically, SBCL conducts from 250,000 to more than 300,000 tests per month for a broad spectrum of the American workplace.
4. The number of cocaine treatments delivered by treatment centers participating in the *Treatment Episode Data Set* (*TEDS*) data collection program.

While none of these indicators is a direct measure of cocaine consumption (or prevalence), each is logically linked to drug usage, and any price-demand elasticity in the market should logically result in measurable effects in these indicators when price excursions occur.

To quantify the sensitivity of the indirect usage indicators to changes in price, a measure of elasticity is defined to be the local non-dimensional slope of the indirect usage indicator *vs*. price index curve. "Non-dimensional" implies a normalization by the respective means of the two variables. The estimate of the elasticity of a usage indicator is primarily determined by the periods in which largest excursions in the *STRIDE* street price index and in the usage indicator occur. These periods typically extend for short periods of time, during which large shifts in the underlying demand are unlikely. In the figures presented in this chapter, the street price index is compared to each of the four indirect indicators and in all cases the slopes are approximately constant. In all cases, the binning parameter, L, is adjusted to match the sampling interval of the relevant indicator.

Figure III-1 shows the correlation between the *STRIDE* street price index and the number of *DAWN* cocaine emergency room mentions by month for ages 12 to 35. The age range has been restricted to the younger population because the older population is known to have a much higher probability of visiting the emergency room as the result of a single use incident than the younger population. This fact can significantly bias the time dependence of the probability that a drug use episode will result in an emergency room visit. The top panel of Figure III-1 shows the price index, the middle panel the *DAWN* emergency room numbers, and the lower panel the nondimensional data (generated by dividing through by the means), along with the "best-estimate" regression line (bold line) and the 95th percentile confidence interval (thin line) derived using a bootstrap procedure on the data (Efron and Gong, 1983; Efron, 1990). Assuming equal errors in the two variables, 10,000 bootstrapped replications of the data were used to yield a median value for the linear regression slope (used here as the "best estimate") of e = –0.63 + 0.06. The assigned error corresponds to one standard deviation in the bootstrapped distribution. The 95th percentile confidence interval, as determined by the bootstrapped distribution, is $-0.86 < e < -0.50$, and the standard, least-squares regression coefficient is R = –0.71. The broad 1990 feature is clearly resolved in both variables, but other features clearly resolved in the price index are poorly resolved in the *DAWN* data. Nonetheless, the two curves are not wildly discordant. Such a correlation was first reported by Hyatt and Rhodes (1992, 1995); however, the claimed correlation was criticized as "coincidental," *i.e.*, "correlation does not imply causality," and several alternative interpretations have been proposed for the *DAWN* data.

Figure III-2 shows the correlation between the *STRIDE* street price index and the *DUF* cocaine testing positive rate. The top panel shows the price index, the middle panel the *DUF* cocaine positive rate, and the lower panel the nondimensional data along with the best estimate result using the bootstrapped linear regression procedure described above. Assuming equal errors in the two variables, 10,000 bootstrapped replications of the data yield a best estimate of $e = -0.29 \pm 0.07$, a 95th percentile confidence interval of $-0.51 < e < -0.19$, and a standard, least-squares regression coefficient of R = –0.64.

Figure III-3 shows the correlation between the SBCL cocaine positive test rate for the combined workforce and the *STRIDE*-derived street price index. The top panel shows the price index, the middle panel the SBCL positive rate, and the lower panel the nondimensional data along with the best estimate result using the bootstrapped linear regression procedure described above. Assuming equal errors in the two variables, 10,000 bootstrapped replications of the data yield a best estimate of $e = -0.60 \pm 0.13$, a 95th percentile confidence interval of $-0.98 < e < -0.29$, and a standard, least-squares regression coefficient of R = –0.51.

Figure III-4 shows the correlation between the *STRIDE* street price index and the fraction of *TEDS*-reported treatments linked to cocaine (cocaine reported as primary or secondary abuse drug). The top panel shows the price index, the middle panel the TEDS fraction linked to cocaine, and the lower panel the nondimensional data along with the best

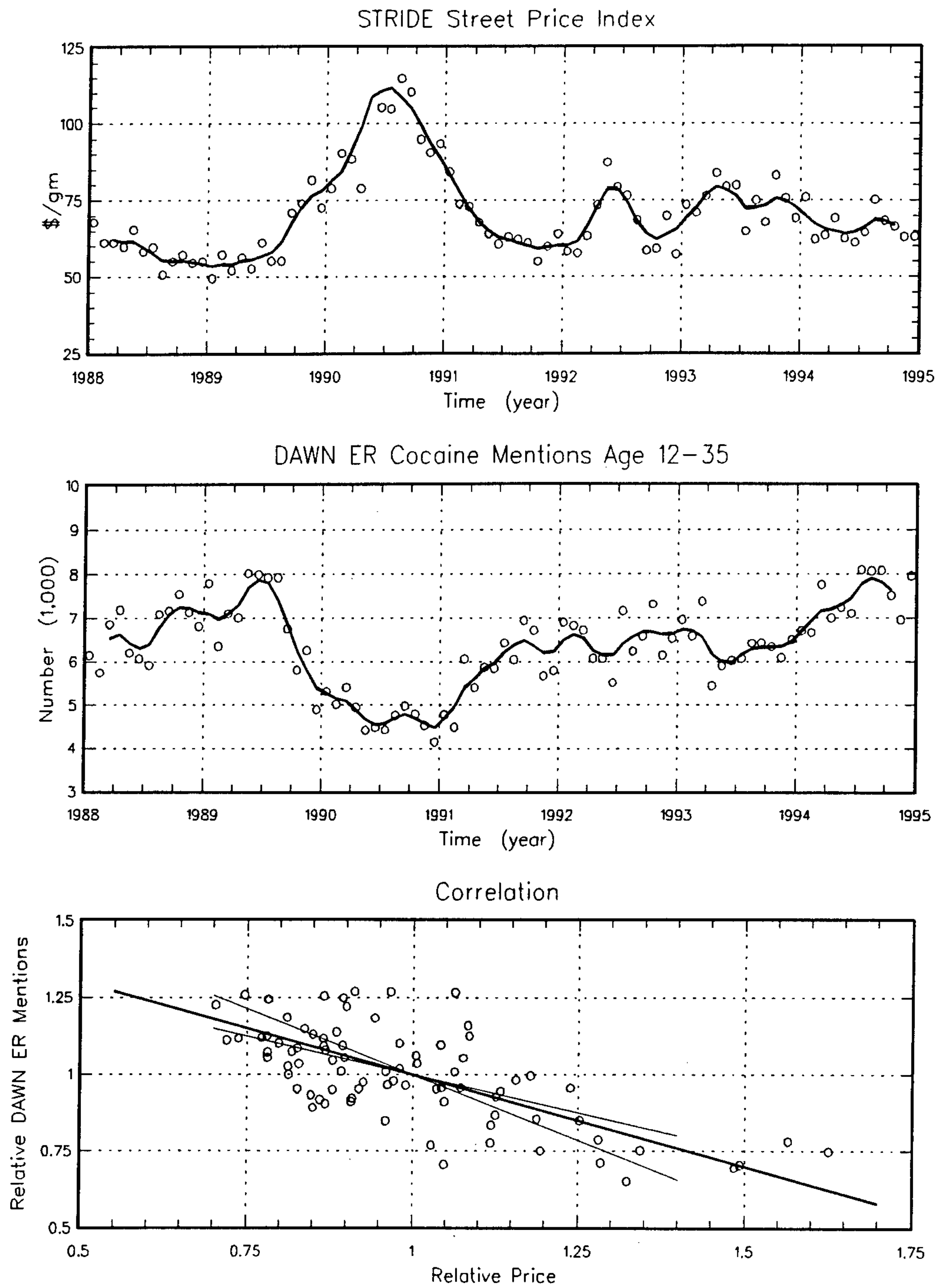

Figure III-1. Correlation between the *STRIDE*-derived cocaine street price index and the number of *DAWN* emergency room cocaine mentions.

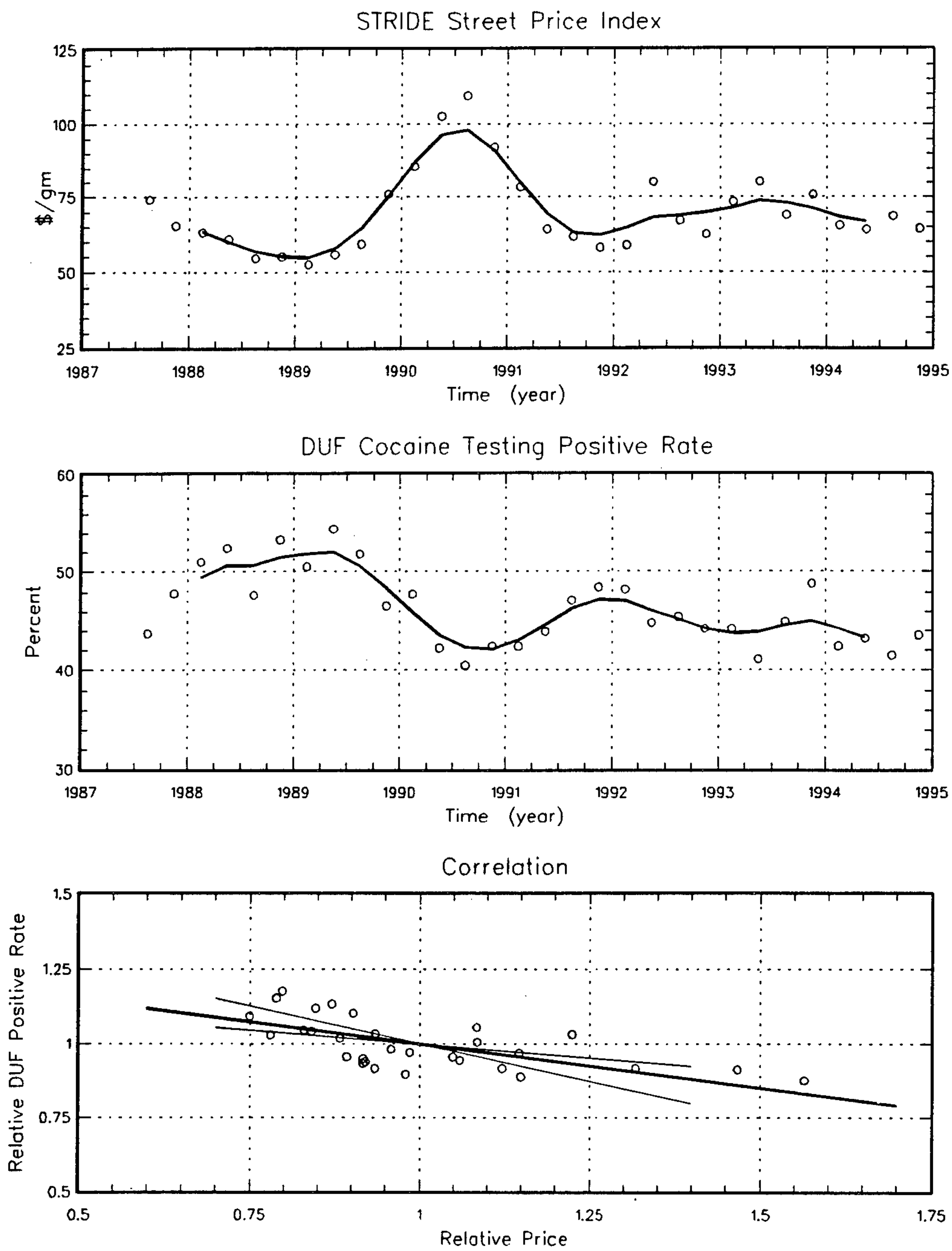

Figure III-2. Correlation between the *STRIDE*-derived cocaine street price index and the *DUF* cocaine positive rate.

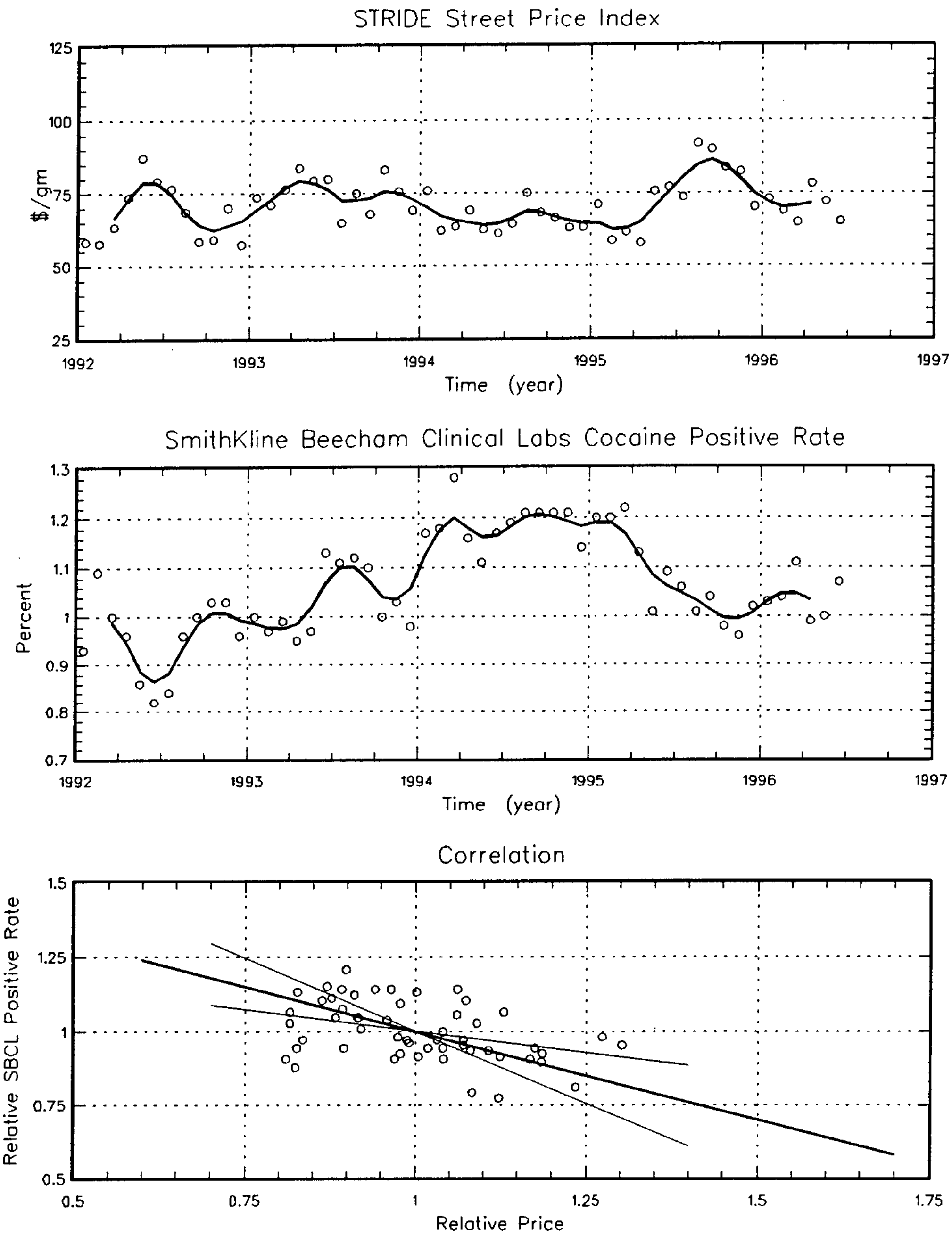

Figure III-3. Correlation between the *STRIDE*-derived cocaine street price index and the SmithKline Beecham Clinical Laboratories combined workforce cocaine positive test rate.

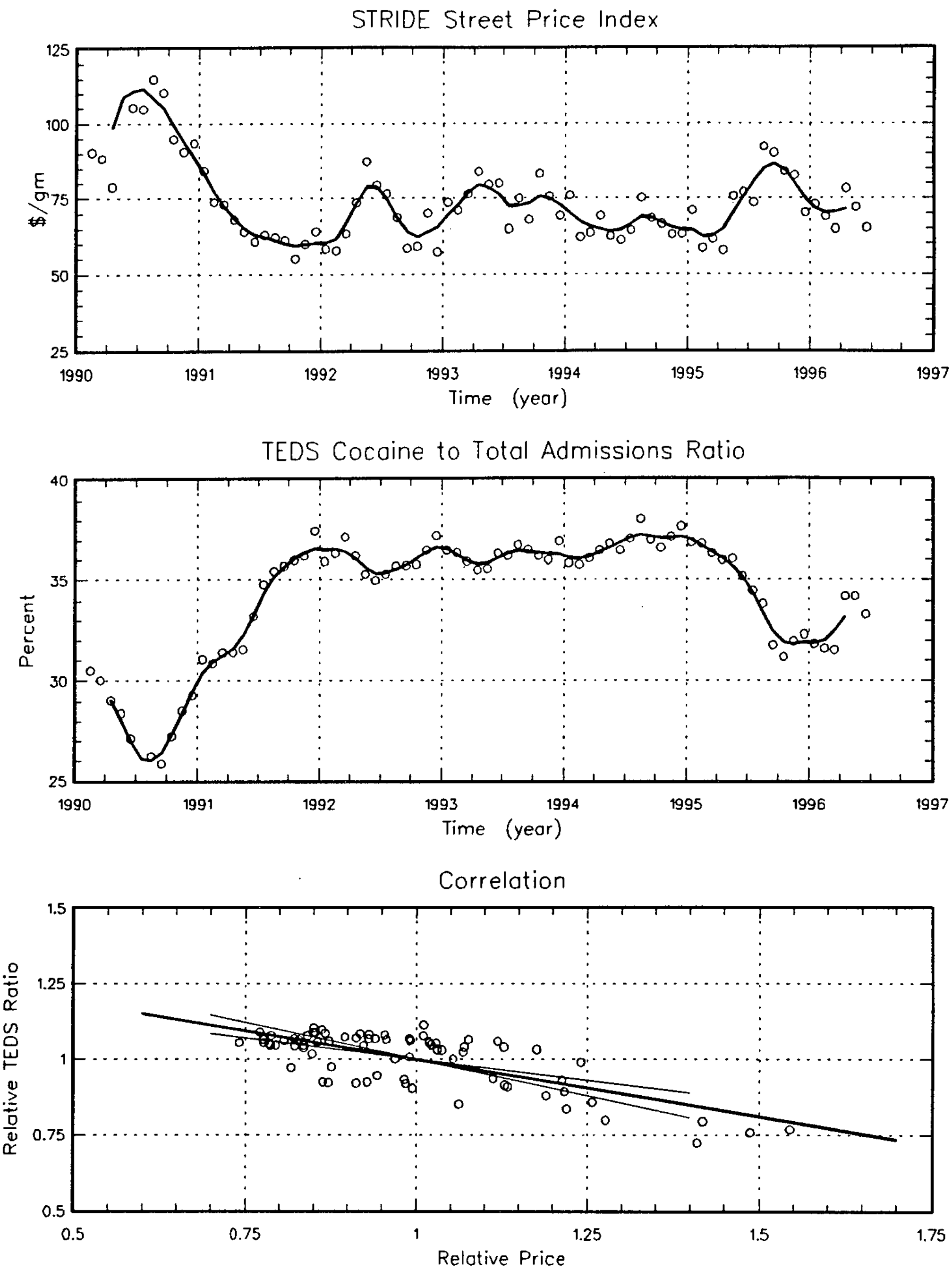

Figure III-4. Correlation between the *STRIDE*-derived cocaine street price index and the percentage of *TEDS* treatment center cocaine admissions.

estimate result using the bootstrapped linear regression procedure described above. Assuming equal errors in the two variables, 10,000 bootstrapped replications of the data yield a best estimate of $e = -0.38 \pm 0.05$, a 95th percentile confidence interval of $-0.49 < e < -0.29$, and a standard, least-squares regression coefficient of $R = -0.73$.

Table III-1 summarizes the estimates of price elasticity as determined from the four indirect measures of cocaine use. In interpreting the correlations observed between the *STRIDE* price excursions and the four indirect usage indicators, it is appropriate to recognize that these usage indicators reflect completely independent processes from disparate populations. The fact that all four show substantial correlation with the *STRIDE*-derived street price index strongly supports the hypotheses that the excursions in the data do reflect meaningful changes in price and purity as experienced on the streets of the U.S., and that these excursions are indeed responsible for the changes in the usage indicators.

The canonical value of the *price elasticity of demand* for cocaine that is commonly used in the literature seems to be about −0.5, based on extrapolated knowledge from other drugs such as alcohol and tobacco. Few measurements are available, however, and those are not in good agreement. Di Nardo (1993) finds no effect on cocaine use due to price changes, Grossman *et al.* (1996) find a range of −0.7 to −1.7, while Saffer and Chaloupka (1996) find a value of −0.28 based on an analysis of the *National Household Survey on Drug Abuse* (see Saffer and Chaloupka, 1996 for a discussion and historical perspective).

Table III-1. Summary of Price Elasticity Estimates for Various Indicators of Cocaine Usage

Usage Indicator	Best Estimate	95% Confidence Interval	Regression Coefficient
DAWN	−0.63	$-0.86 < e < -0.50$	−0.71
DUF	−0.29	$-0.51 < e < -0.19$	−0.64
SBCL	−0.60	$-0.98 < e < -0.29$	−0.51
TEDS	−0.38	$-0.49 < e < -0.29$	−0.73

While it is apparent that the "elasticities" of the indirect usage indicators developed above are each related to the price elasticity of demand for cocaine, those relationships are imprecisely understood. In addition, as noted previously, the "elasticity" determined for these indicators neglects intrinsic shifts in demand, believed to be small, that may have occurred during the period examined. Therefore, the slopes of the regression lines provide only an approximate measure of the true price elasticity of demand. Nonetheless, the "elasticities" determined above for the four indirect usage indicators are consistent with the canonical value of −0.5 as being a reasonable estimate of the price elasticity of demand, averaged over the entire user function.

CHAPTER IV

THE EFFECTS OF INTERDICTION CAMPAIGNS ON THE COCAINE MARKET

IV. THE EFFECTS OF INTERDICTION CAMPAIGNS ON THE COCAINE MARKET

A. TIMING OF INTERDICTION EVENTS

This section examines the timing of major interdiction events, primarily in the source-zone, as they relate to the price and purity excursions observed in Figures II-8 and II-9, and, based upon the timing coincidences between the price and purity excursions and these interdiction events, argues that the interdiction campaigns are primarily responsible for the excursions.

Figure II-8 shows that, prior to 1989, the street price for pure cocaine was generally falling. Undoubtedly, a number of factors contributed to this decreasing price, e.g., the supply of cocaine increased markedly in the late 1970s and early 1980s from increasing competition in response to the perceived growth in the U.S. cocaine market throughout the late 1970s, only to be faced by a reduced demand as the national proclivity for drug use began to wane in the mid-1980s.

After 1989, price and purity data show a less smooth history with several episodes of rises and falls. One can postulate that the street price fluctuations seen in Figure II-8 and the purity fluctuations seen in Figure II-9 after 1989 are correlated with large-scale attempts by the U.S. and source nations to disrupt the flow of cocaine into the U.S. The four most prominent features in the data, those centered on 1984-85, 1990, 1992, and 1995, can be readily associated with the four major interdiction efforts spearheaded by the U.S. and the source nation governments. These are (1) the DEA-led initiative known as *Operation ChemCon*, (2) the initiation of the Bush Administration's *War on Drugs*, (3) the conduct of *Operation Support Justice III*, and (4) the implementation of the shoot-down policy against trafficker aircraft by the government of Peru.

Operation ChemCon was a major effort by the DEA to "bug" cocaine precursor chemical containers at the source so that they could be tracked to processing centers. The operation culminated in 1984 with the discovery of a very extensive laboratory complex near the town of Tranquilandia, Colombia. Colombian police, DEA, and other U.S. agencies seized enormous quantities of fuels and chemicals essential for the processing of coca paste into cocaine hydrochloride. The street price index and purity data indicate that the repercussions of this operation on the cocaine market were immediate and significant. Unfortunately, because cocaine market prices were in "free-fall" at the time, the resulting price increases were small (but clearly resolved). The purity drop shown in Figure II-9, however, was deep and sustained for more than one year. Unfortunately, no analysis of price and purity data was conducted at the time, and *Operation ChemCon* was deemed a failure by the DEA. The industry's recovery, apparently completed some 18 months after initiation, was presumably the result of adaptation. Although little, if any, quantifiable evidence for this can be found, anecdotal accounts abound.

The major activity hailed as the *War on Drugs*, initiated by the Bush administration in 1989, was a multi-faceted effort with a preponderant emphasis on interdiction. These interdiction actions were primarily focused in the transit-zone of the Caribbean, but enhanced operations in the source nations also disrupted the production/distribution machinery of the cocaine industry. In 1989, most cocaine was transported by trafficker aircraft to areas south of the U.S. border where it was smuggled across. In late 1989 an extensive air surveillance system was put in place involving airborne early warning aircraft, deployable ground-based and naval radars, and apprehension teams. As an example, the number of airborne early warning aircraft flight hours increased nearly tenfold to many thousands of flight hours per month at the peak in a trend nearly coincident with the rise in price index. Sufficient operational activity was provided to cover completely three principal air trafficking routes. The timing of the ramp-up of flight hours is consistent with the hypothesis that the air surveillance system was a major (but not necessarily the only) contribution to increasing the risk and cost to the air traffickers. Large dislocations of coca workers were reported at that time in the news media. However, the interdiction operation was not sustained because a large reduction in resources (the flight hours were rapidly cut almost in half within a month) took place after September 1990 as U.S. military forces deployed to the Persian Gulf in response to the Desert Shield build-up. This drawdown of interdiction assets, along with trafficker adaptation, are likely causes of the recovery of cocaine price and purity to pre-1989 levels, as shown in Figures II-8 and II-9. The single largest adaptation effect was the establishment of new business relations, with what are now known as the Mexican transportation cartels, for transportation services over Mexican land routes.

Operation Support Justice III, initiated in late 1991, focused on suppressing the movement of coca products out of Peru's Huallaga Valley. By early 1992, the Peruvian Air Force aggressively pursued trafficker aircraft, resulting in a few, but significant, losses.

This operation also was not sustained; it was concluded in May 1992 because of a diplomatic incident. This action and the subsequent operation suggested that the perception of risk was enough to raise the fees for transportation services from Peru to Columbia, and that these increased fees propagated rapidly throughout the distribution network to raise prices noticeably at all levels of the market.

By the spring of 1994, a major debate emerged over the legality of the U.S. providing data to source-zone host nation forces on suspected drug trafficker aircraft, when it could be reasonably anticipated that the host nations might shoot down suspect aircraft failing to obey instructions to land. The refusal to provide such data culminated in the suspension of all U.S. interdiction efforts within the source nations from May 1994 through the early part of 1995. In March 1995, nine months after the suspension of interdiction efforts in the source nations relying on U.S. support, the price of cocaine in the U.S. reached an all-time low.

The President proposed and the Congress enacted legislation in 1994 to enable the U.S. to assist host nations with tracking data. In early 1995, the government of Peru implemented a shoot-down policy against trafficker aircraft. Since April 1995, the governments of Peru and Colombia, assisted by tracking data from many U.S. agencies, have successfully shot down or otherwise destroyed dozens of trafficker aircraft flying the so-called "air bridge" from the growing regions of Peru to the processing centers in Colombia. As shown by Figure II-8, from March of 1995 to September of 1995, cocaine prices in the U.S. surged to a five-year high.

By October 1995, cocaine prices were again heading down (although the purity of cocaine seemed not to have recovered fully). As of this writing (October 1996), the "air bridge" has not been reconstituted and, once again, trafficker adaptation may be credited for the price reversal. However, an alternative explanation has been suggested. Starting in the middle of 1995, as cocaine prices were rising rapidly, several "kingpins" of the Cali cartel were arrested or killed. Many Colombian growers and traffickers have expressed the opinion (Weisman, 1995) that removal of dominance by the Cali cartel has opened new avenues of competition, driving prices down. This point should not be overlooked.

Figure IV-1 is a reproduction of Figure II-8 annotated to show the beginning of the eight major source-zone actions conducted since 1984, as identified by the historian

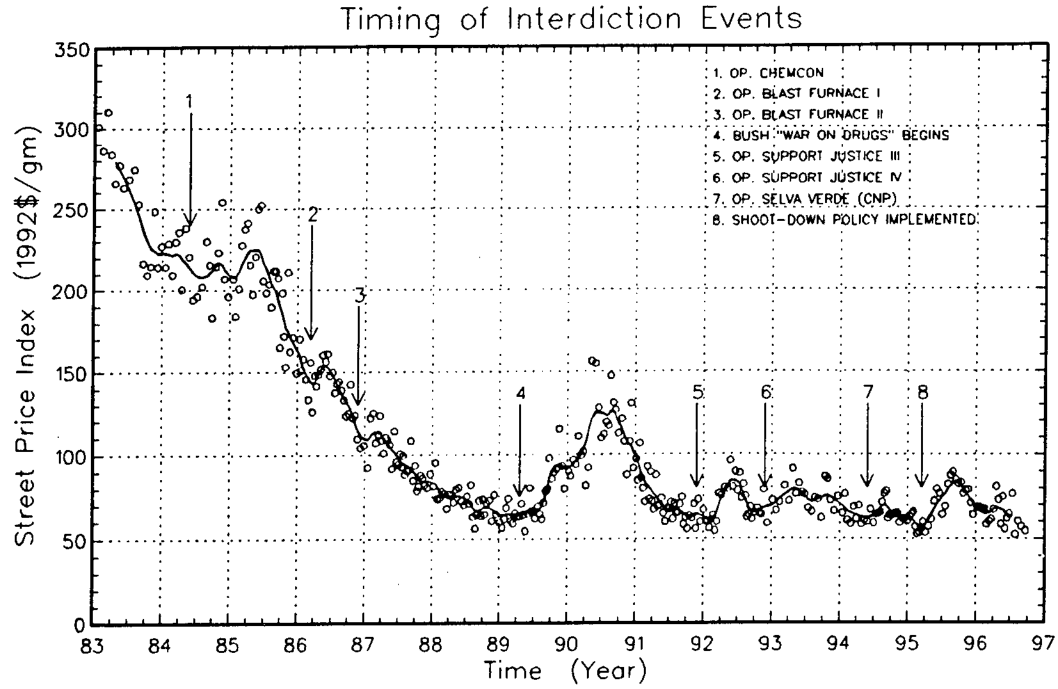

Figure IV-1. Price history of the U.S. cocaine market with superimposed time markers showing the timing of all major source-zone interdiction events since 1980.

of U. S. Southern Command.[1] In addition to the four events previously discussed, several additional events are indicated on Figure IV-1:

- *Operation Blast Furnace I.* The U.S. disrupted the Chapare growing region of Bolivia using mobile teams of the Bolivian Army and police transported by U.S. helicopters.
- *Operation Blast Furnace II.* This was a follow-on disruption similar to Blast Furnace I.
- *Operation Support Justice IV.* This operation was characterized by much less aggressive operations than Support Justice III and few end (arrest) actions. It was terminated when the U.S. denied tracking data assistance from May 1994 to December 1994 because of a dispute over Allied nation shoot-down policies.
- *Operation Selva Verde.* This operation was conducted by the Colombian National Police against cocaine processing laboratory complexes. This event

1 The historian of U. S. Southern Command identified ten events – those shown on Figure IV-1 plus Operations Support Justice (SJ) I and II. SJ I and II are not included in Figure IV-1 since further examination has shown that these operations were not, in themselves, major operations in the source zone. Rather, they established the international cooperation, increased deployed assets, and provided training that was later employed effectively in operations SJ III and IV.

occurred during the period when the U.S. had terminated information sharing and support for Colombia and Peru because of legal restrictions on U.S. personnel.

Caution is warranted when associating cause with a single correlation, or even with multiple correlations that occur without logical relationships. However, in view of the consistent pattern observed between source-zone interdiction events and excursions in the *STRIDE*-derived street price index, source-zone interdiction activities are the most reasonable explanations for the major price and purity excursions. In fact, other than random events, no other explanation for these consistent patterns has been offered. This does not necessarily imply that all of the observable excursions in the price and purity data are attributed exclusively to source-zone interdiction activities; however, in terms of market economic dynamics, the mechanism is quite plausible and consistent with the data.

There is further evidence that the source-zone interdiction activities described above did produce major market disruptions of the cocaine industry. Figure IV-2 depicts

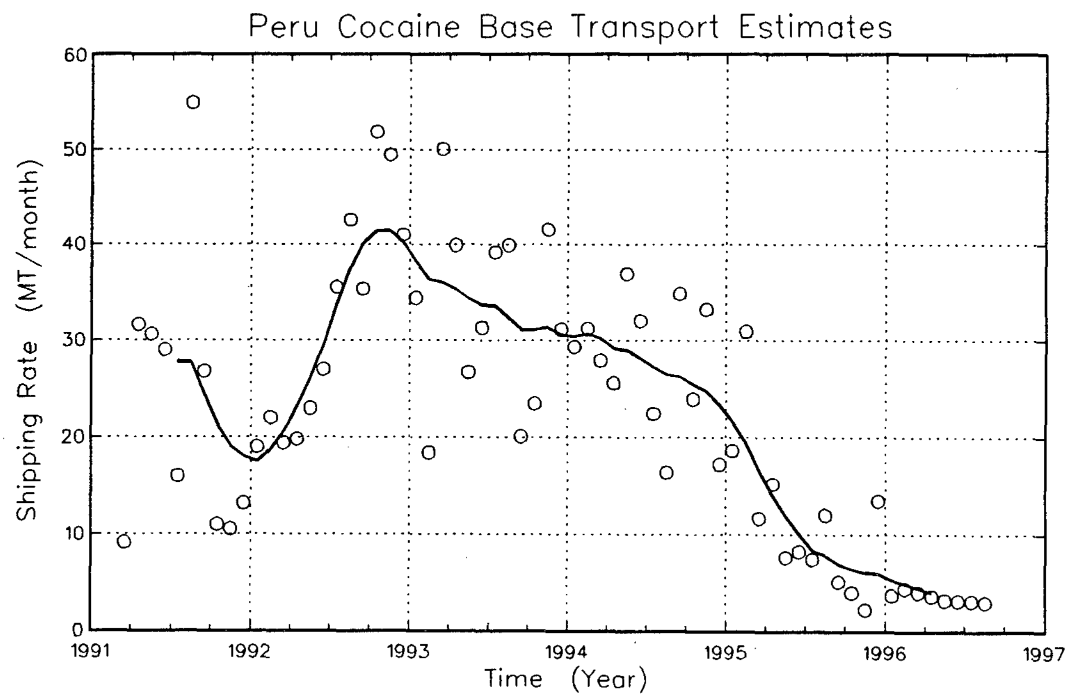

Figure IV-2. Estimates of coca base transport on the air bridge from Peru to Colombia.

the quantity of cocaine base transported along the air bridge as estimated by the Peru Tactical Assessment Team[2] (TAT). The figure shows a significant decline in cocaine base transported by air from Peru to Colombia starting in the third quarter of 1991 until the spring of 1992. Another significant decline began in March 1995, coincident with aggressive interdiction by the Peruvian Air Force of trafficker aircraft that resulted in shootdowns of aircraft resisting apprehension.

Classified radar tracking data confirm that air traffic all along the air bridge has plummeted since March 1995 and the number of observed flights has declined to about one-tenth of previous numbers. As of this writing, the air bridge has not been reconstituted. It is now generally believed, and supported by intelligence and newspaper accounts from the region, that trafficker organizations have been forced to much greater reliance on river and land routes to export base materials out of Peru. Because surface operations are much more costly and complex due to the high risks associated with maintaining security, the industry may have undergone a structural and perhaps permanent change with noticeably increased costs.

For severe disruptions of transportation of base from Peru to Colombia, the price of base in the growing regions of Peru would be expected to drop dramatically because the farmers cannot sell either leaf or base. Figure IV-3 displays data on the estimated cost to produce base in Peru (open squares) and the price that traffickers pay for base in Peru (open circles). The price data are primarily from the Peruvian *Projecto Especial Alto Huallaga* (PEAH) (PEAH, 1996) and are based upon sampling of prices at 15 or more locations in the Upper Huallaga Valley and a few other regions. The data prior to 1993, which are less accurate, were compiled by the U.S. Agency for International Development (USAID, 1981, 1983), from a variety of sources prior to the PEAH project. The United Nations Drug Control Project also has collected leaf, paste, and base prices since 1989, and these are consistent with the PEAH data (UNDCP, 1996.) The estimates of the cost to produce base include the chemical, labor, and processing costs and PEAH prices for raw coca leaf (or paste) (Cuanto, 1993). Sharp decreases in the price for base are apparent and correspond to the timing of the *War on Drugs*, *Operation Support Justice III*, and the implementation of the shootdown policy in 1995. This figure indicates that the

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2 The TATs are multi-agency bodies that operate in each host nation embassy to support the activities of the DEA within the host nations. The TATs work closely with host nation police and military intelligence organizations to monitor drug-related activity.

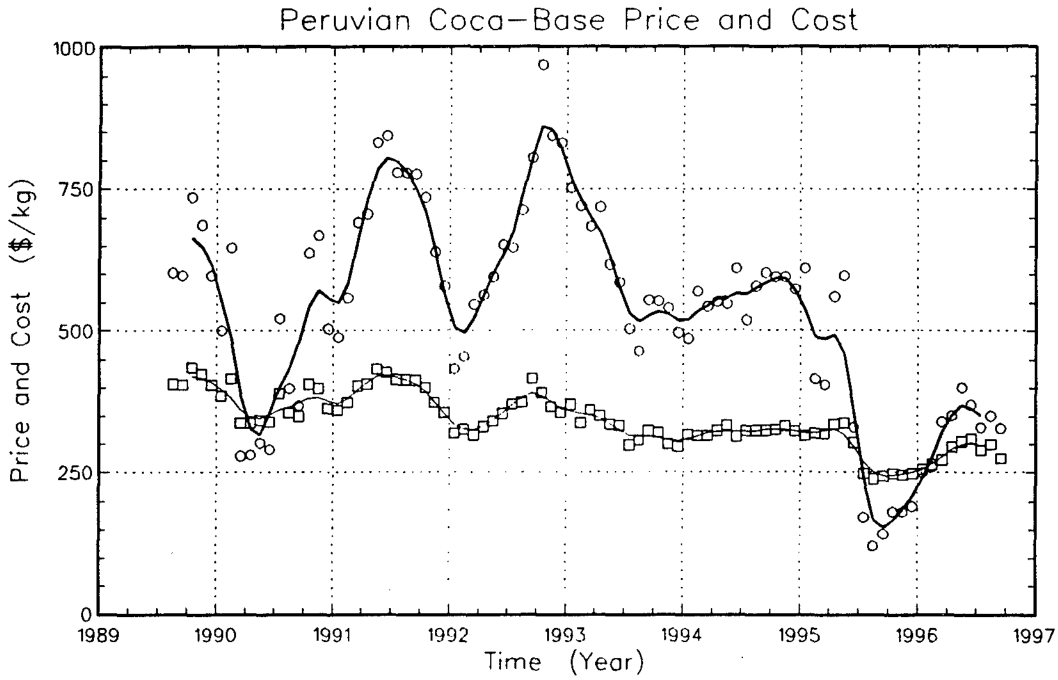

Figure IV-3. History of coca base price (circles) and estimated cost (squares) in Peru.

average price of base plummeted to or below the average cost to produce during 1995, and that the margins between cost and price remain far smaller than those throughout the 1991-1995 period. These estimates of reduced profitability since the shootdown policy in 1995 are consistent with reports during 1995 of the displacement of large numbers of cocaine workers in Peru (Craig, 1995), and commensurate requests for food assistance for displaced workers (U.S. Embassy, Peru, 1995).

B. THE LONG-TERM BENEFITS OF INTERDICTION

In the preceding section, we argued that several interdiction actions, primarily in the source-zone, have been responsible for short-term, but significant, increases in the street price of cocaine in the U.S. These price increases, in turn, have been associated with decreases in cocaine use patterns. We cannot, with confidence, make definite predictions about the long-run price effects of interdiction. Interdiction is a recent policy, and even during its brief life span, it has not been consistently pursued. We do not know what long-term market responses interdiction will produce, and no amount of study, at the present time, can answer this question.

We nonetheless challenge the common view that interdiction necessarily is ineffective in the long run and argue instead that properly focused interdiction efforts can force a structural change in the market, resulting in a long-term increase in price. The logic underlying this argument is twofold. First, cocaine production and distribution are motivated by profit and attempt to establish the most efficient distribution channels. If a well-conceived interdiction activity permanently blocks an established distribution channel, the enterprise is forced to adapt by developing an alternative and less efficient channel, with commensurate increases in costs. This permanent increase in costs will be reflected in a permanent increase in prices. Second, in a market in which prices are declining because of increasing competition and decreasing demand, the sudden appearance of new risk within the industry can cause a sudden change in the rate at which new competition enters and correspondingly the rate at which prices decrease.

As an example of the first mechanism, we have already mentioned that a major result of the 1989 "war" was the establishment of new business agreements between the cocaine producing organization and the recently formed Mexican transportation cartels. The business sanctions imposed by this new partnership were effectively an immediate doubling of the marginal costs of producing and importing a unit of product, since the fee charged by the Mexican cartels is typically one-half the cocaine to be transported.

Many studies also assume that inventory accumulation blunts the price effects of interdiction. This claim is no more than partially correct. First, many interdiction effects cannot be blunted by inventory accumulation. The Peruvian air bridge, for instance, restricts the supply of coca base to Colombian laboratories, but also raises the costs of accumulating inventories. In this respect, the air bridge policy should act to lower inventories, not raise them. Some interdiction policies, such as coca leaf eradication programs, may be blunted by inventory responses, but many other forms of interdiction, such as raising transportation costs, make inventory responses more costly as well.

Second, long-run adjustments, such as those that might occur in inventories, do not imply that interdiction has no effect on the street price of cocaine. The mere expectation of interdiction can induce higher inventories, thereby raising the marginal cost of production, and thus the street price of cocaine. Price spikes may disappear, but the price of cocaine will be permanently higher, due to higher inventory costs and other adjustment costs. Over time we should expect the price spike to diminish, and the price effects of interdiction to be spread out and smoothed. But the price effects will remain real, even though they become apparently invisible; they simply have become permanent and smoothed, rather than spiked and concentrated at particular points in time.

In the long run, if interdiction is pursued regularly, the price series for cocaine may be perfectly smooth. In the relevant graphs, we would see that stepped-up interdiction has no effect on market price at the street level. Such results, however, would not imply that interdiction is ineffective in raising price. Interdiction still would be raising the overall base for (temporally flat) cocaine prices by raising inventory and adjustment costs.

Observational data suggest that a structural change occurred in the cocaine industry in 1989. Figure IV-4 shows a plot of the median gross (i.e., uncorrected for purity) unit-price for all *STRIDE* data since 1983. Each open circle represents the median value of 100 time-sequential purchases, and the bold line is the usual nonparametric regression curve. The salient feature of the curve that supports the argument for a structural change in the industry is the sudden change in slope or "kink" that occurred early in 1989. In view of the temporal correspondence of this "kink" with the implementation of the *War on Drugs*, we attribute this structural change to the imposition of the extensive interdiction network placed between the product source and its market.

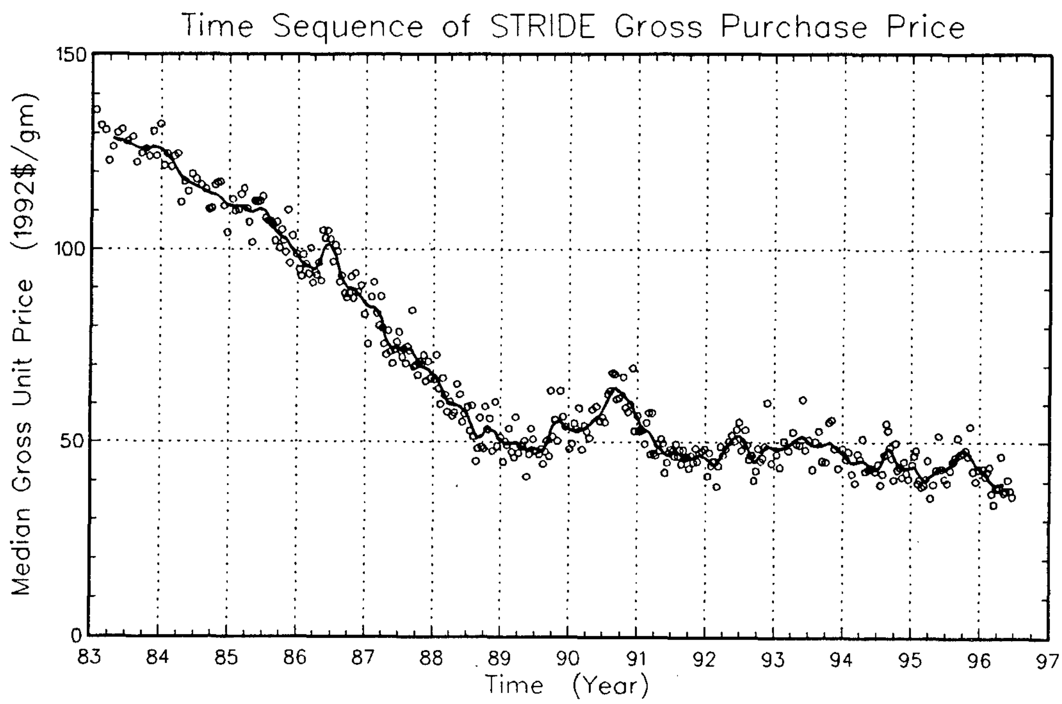

Figure IV-4. Time history of *STRIDE* median gross purchase unit-price from 1983 to mid-1996.

Accepting the hypothesis that the interdiction focus of the *War on Drugs* caused the observed shift in the price curve should not be interpreted as a minimization on the part of the authors of the effects of numerous other factors on cocaine prices in general.

Indeed, one can readily argue that U.S. Customs Service actions to inhibit import of cocaine at the U.S. borders, aggressive domestic law enforcement, and severe sentencing of drug dealers are all contributing components of policies aimed at reducing supply. However, we are unable to identify specific dramatic changes in these aspects of supply control that correlate in time with the observed shift in the price data slope.

The dramatic change in the slope of the street price of cocaine occurring in 1989 is also clearly evident in the normalized price of cocaine – the street price index. Figure IV-5 shows the street price index from 1985 along with the "trend" line that characterized the price between 1985 and 1989. The trend line indicates that between 1985 and 1989, the price index was declining, following an approximately exponential path.[3] The smooth thin line is the result of an exponential fit to the data between 1985 and 1989. The extrapolated street price index will serve as the basis for our estimate of the cost-effectiveness of total interdiction in section C.2. below.

Figure IV-6 presents a more detailed depiction of the last eight years of the price index shown in Figure IV-5, highlighting that several transient excursions have occurred since 1989 with varying effects. The large 1990 feature, we have hypothesized, was due to the combined effects of all interdiction efforts – source-zone and transit-zone – but the other features (after 1992) are primarily the result of source-zone activity. We have previously noted that, when the U.S. "turned off" its source-zone interdiction machinery in late 1994, the street price index reached an all-time low of about $50 to $55 per gram within nine months. This is consistent with the existence of a baseline "floor" value for the market on top of which all transient increases are superposed. This baseline, shown as the solid horizontal line in Figure IV-6, at a level of approximately $55 per gram is interpreted as the baseline price index in the absence of source-zone interdiction efforts.

When averaged over the last five years, the price index accounts for approximately a 30 percent increase over the floor baseline. This average effect is shown as a dash line in Figure IV-6. The difference between the floor price and the average level is interpreted as the average benefit of the source-zone interdiction program since 1992.

3 This functional behavior is the subject of continuing research to be addressed in a forthcoming IDA paper.

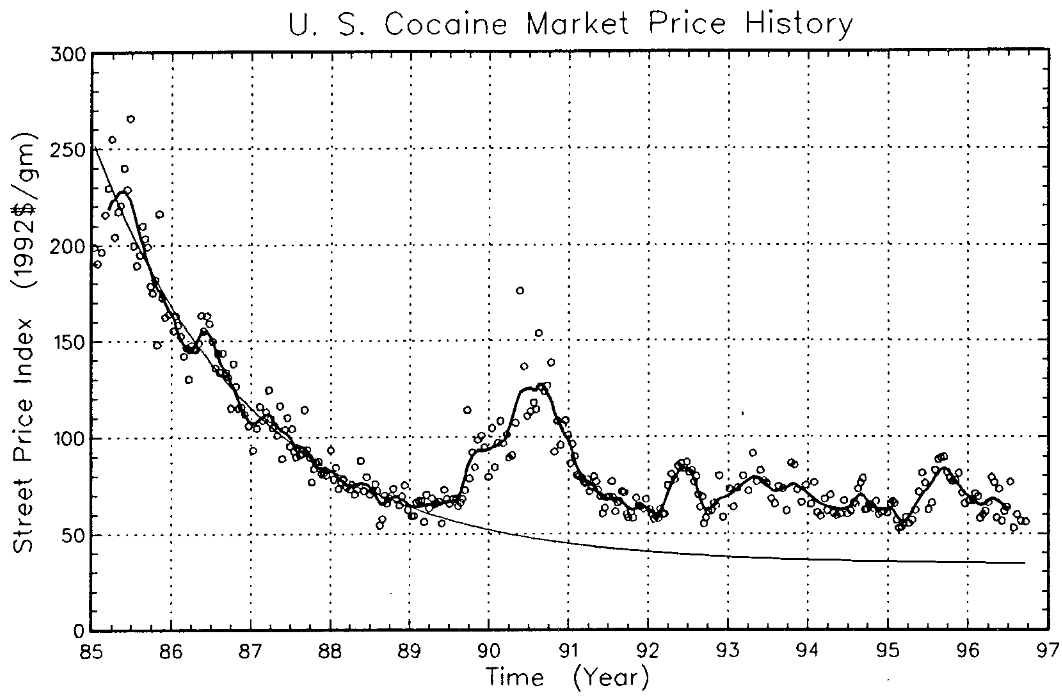

Figure IV-5. Street price index of cocaine since 1985.

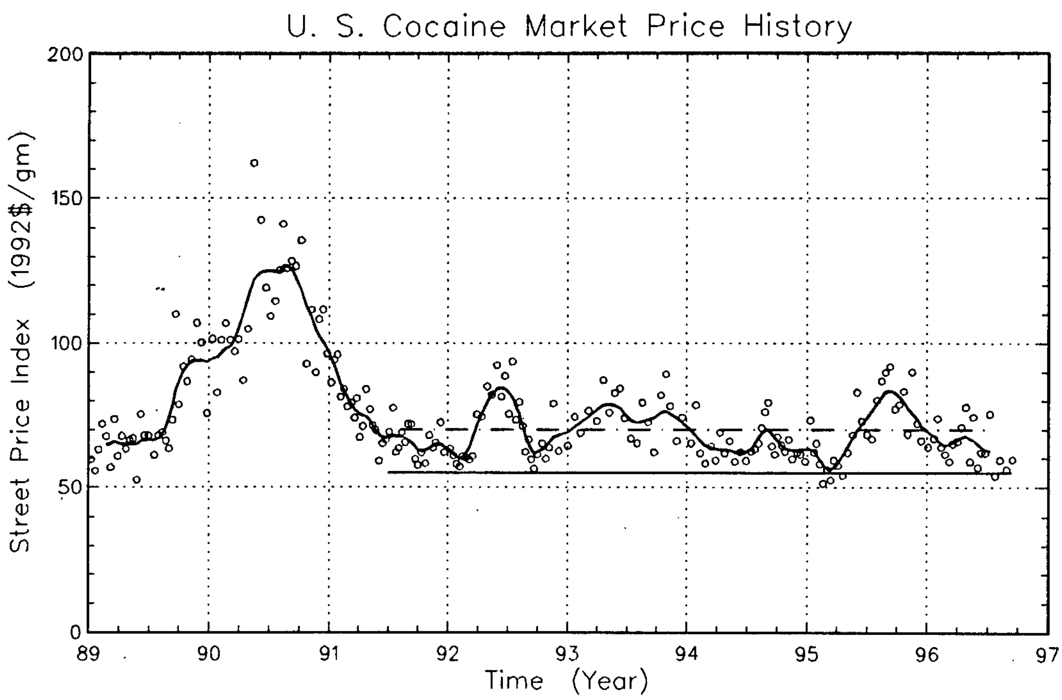

Figure IV-6. Detailed view of the street price index since 1989.

Additional support for the thesis that source-zone interdiction activities can cause structural changes in the U.S. market is provided by Figure IV-7. This figure shows the *STRIDE* median normalized unit-price and median purity for all transactions restricted to small purchase quantities (in the normalized volume range of 0 to 10 grams). This is the volume range typically used as representative of the "retail" street market. Evident from this figure is a distinct decrease in median purity, driving a commensurate increase in price, beginning in April 1995. The two straight lines in each figure are meant to point out the trend baselines prior to and after the transition time of April 1995. This transition time correlates well with the initiation of the shoot-down policy by Peru. This coincidence is consistent with the thesis that the shoot-down policy is responsible for the observed price and purity changes. One cannot determine if these higher "retail" prices will continue indefinitely, or, alternatively, if effective adaptation by traffickers will eventually return prices and purity to the pre-April 1995 levels. Nonetheless, the effect is clearly of significant duration and continues to persist to date.

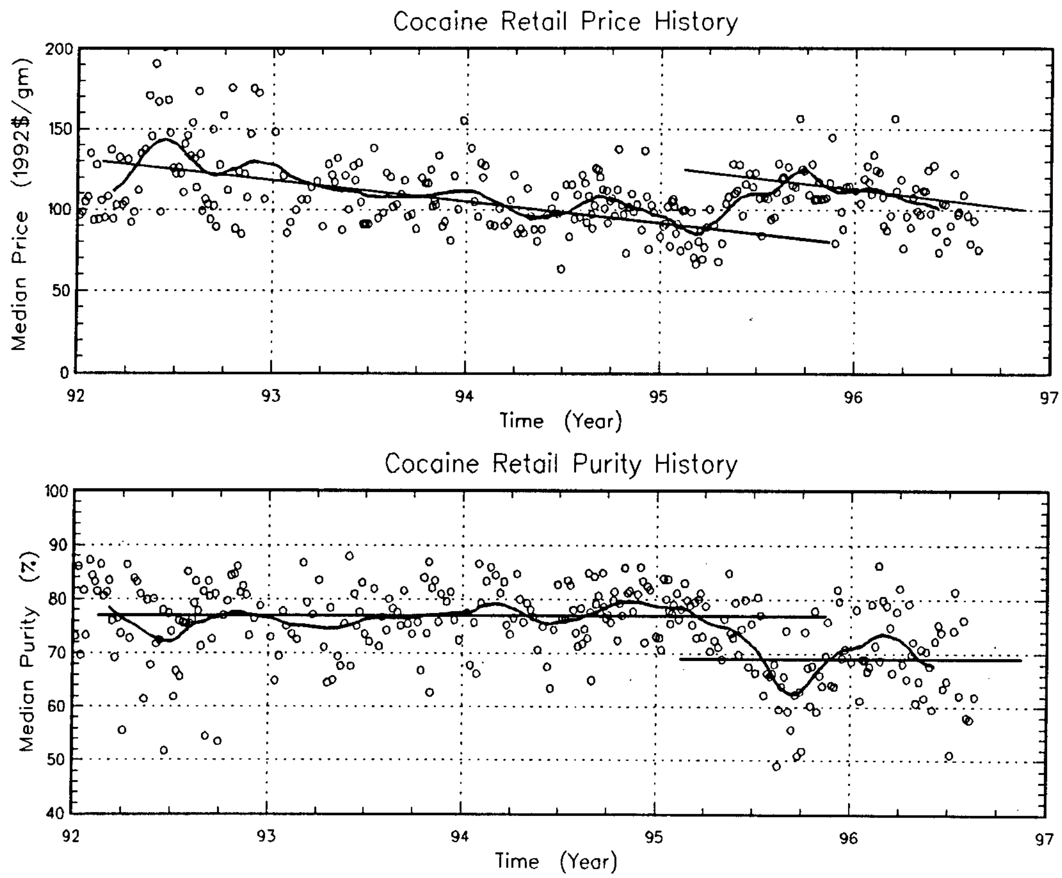

Figure IV-7. History of median normalized unit-price and median purity for all *STRIDE* purchases in the range (0 and 10 grams) of normalized purchase volume since 1992.

Earlier in this chapter, we associated the shoot-down policy with markedly decreased traffic along the air bridge and with a significant decrease in the profitability of producing base in Peru. These occurrences, considered collectively, lend strong support to the thesis that this source-zone effort has indeed caused a structural change in the production and transportation elements of the cocaine industry, resulting in higher long-term prices of cocaine in the U.S. domestic market.

C. THE COST-EFFECTIVENESS OF INTERDICTION

The preceding section argued not only that interdiction activities have produced transient increases in the street price of cocaine, but also that these activities have resulted in long-term price increases and a commensurate decrease in the consumption of cocaine in the U.S. This section develops rough estimates of the cost-effectiveness of these interdiction activities. While the estimates provided are necessarily imprecise, they are of the correct order of magnitude and are, therefore, useful in assessing the relative cost-effectiveness of interdiction efforts within the context of the overall program to reduce cocaine use in the U.S.

1. Cost-Effectiveness of Source-Zone Interdiction

The previous discussion of Figure IV-6 suggested that the transient price increases associated with source-zone interdiction activities since 1992 have caused the street price of cocaine to be, on average, approximately 30 percent greater than the floor baseline price. During this time, the U.S. is estimated to have spent approximately \$200-\$400 million per year[4] for source-zone interdiction (ONDCP, 1996), i.e., interdiction against the production or transportation of base or precursor chemicals. If a nominal price-demand elasticity of –0.5 is assumed, then the 30 percent increase in price translates to a 15 percent reduction in demand. If cost-effectiveness is defined as the number of dollars needed to achieve a one percent decrease in cocaine demand, then a rough estimate for the cost-effectiveness of source-zone interdiction is:

$$\text{Cost-Effectiveness} = \frac{15\%\ \text{Reduction in Demand}}{\$200\text{ - }\$400\ \text{million}} = 0.08\text{-}0.04\ \frac{\%}{\$\ \text{million}}$$

or approximately \$13 - \$25 million per year to effect a one percent reduction in demand.

4 The estimate of \$200 to \$400 million as the average annual cost over the 1992 to 1996 period includes the funding for "International DEA," "International Narcotics Matters," and the source-zone portion of "Department of Defense Interdiction" and excludes funding for "Agency for International Development" (ONDCP, 1996).

This empirical estimate is clearly directly applicable only to the experience of 1992 to 1996; *i.e.*, as in any socio-economic system, past performance is no gauge for future performance. In addition, caution is warranted in extrapolating any such estimate of marginal cost-effectiveness to large changes, because the cost-effectiveness is likely to vary in a highly nonlinear and chaotic fashion as the conditions move far from the original equilibrium point. Nonetheless, this admittedly crude estimate does suggest that a well-conceived source-zone interdiction strategy aimed at denying production and transportation to the cocaine industry can be relatively cost-effective.

2. Cost-Effectiveness of Total Interdiction

In the previous section, we have argued that the transitory excursions in the cocaine street price index can be causally linked to source-zone interdiction activity. We now proceed to more speculative ground and argue the case that the overall effect of interdiction has been to keep prices elevated well above what they would have been in the absence of such interdiction.

As noted previously, Figure IV-5 indicates that between 1985 and 1989 the street price index decline is consistent with a smooth, approximately exponentially decaying trend. In mid-1989, this trend line was broken drastically by a sudden reversal of prices that reached a peak in 1990 with a doubling of prices. Although prices recovered by 1992, they never returned to the pre-1989 trend line. Instead, the price index after 1989, disregarding the numerous transient fluctuations, adjusted to a new trend line with a much shallower slope. We believe that this transition was not spontaneous but was induced by the introduction, via the *War on Drugs*, of an extensive interdiction machinery placed between the source of the product and its marketplace.

In the absence of the *War on Drugs*, the accepted economic theory of monopolistic competition argues that prices would have continued to decrease, eventually converging to a value equal to the long-run average cost. It is generally understood that the costs of producing and transporting cocaine to the U.S. are small, i.e., currently on the order of $5 per gram. However, while it is clear that the street price index remains well above the long-run equilibrium price, there is no accepted model with which one might project the path that the street price index would have followed in the absence of the *War on Drugs*, or the number of years that would pass, in reaching the equilibrium value.

As a rough approximation, however, we believe it is reasonable to hypothesize that, in the absence of the *War on Drugs*, the street price index would have continued to follow the exponential trend line observed until 1989, asymptotically reaching an eventual price of approximately $35 per gram. One could readily argue that this value exceeds the "long-run average cost," but the intent is to develop a rough, but not overstated, measure of the impact of the *War on Drugs*. Note that this assumed price decline to $35 per gram incorporates the influence – which we believe to be substantive – of border protection, law enforcement, and legislative actions that were initiated in the 1970s and increased significantly throughout the 1980s.

Following the Bush Administration's war on drugs, the street price and purity of cocaine have never again returned to the pre-1989 path. (Note: The disruption of the air bridge in 1995 has shown a similar kind of sustained effect, but on a smaller scale.) Instead, the street price index since 1989 has been kept elevated at or above a "floor" price of approximately $55 per gram. Consequently, we argue that the street price index increase above the extrapolated value of $35 per gram to the $55 per gram floor price is an overall measure of the efficacy of the entire interdiction effort in the transit and source zones, *i.e.*, the integrated result of U.S. and transit and source-zone government efforts to disrupt market infrastructure and increase production and transportation costs.

Assuming a nominal value of –0.5 for the price elasticity of cocaine demand, it is possible to translate the approximate 60 percent increased price resulting from the overall interdiction effort into a 30 percent reduction in demand. Since we spend approximately a range of $1 billion to $2 billion annually (prior to 1993, $2 billion annually) on this interdiction effort (ONDCP, 1996), the cost-effectiveness can be crudely estimated as

$$\text{Cost-Effectiveness} = \frac{\text{30\% Reduction in Demand}}{\$1{,}000 - \$2{,}000 \text{ million}} = 0.03 - 0.015 \frac{\%}{\$ \text{ million}}$$

or approximately $30 million to $60 million per year to effect a one percent decrease in demand.

Admittedly, the above derivation of an estimate of the cost-effectiveness of overall interdiction is imprecise and subject to reasonable question. Nonetheless, we believe that the data support an approximation of the cost-effectiveness of interdiction in the range of tens of millions of dollars per one percent decrease in consumption.

CHAPTER V

RECONCILING EMPIRICALLY DERIVED ESTIMATES OF COST-EFFECTIVENESS WITH PREVIOUSLY PUBLISHED ESTIMATES

V. RECONCILING EMPIRICALLY DERIVED ESTIMATES OF COST-EFFECTIVENESS WITH PREVIOUSLY PUBLISHED ESTIMATES

The estimate of the cost-effectiveness of source-zone interdiction (and the less firmly based estimate of the cost-effectiveness of interdiction overall) presented in the preceding chapter stands in contrast to a previously published and widely distributed estimate derived through the use of a model to describe cocaine supply and demand. In a paper titled *Controlling Cocaine* (Rydell and Everingham, 1994; see also: Rydell *et al.*, 1996), analytical measures were developed to compare the cost-effectiveness of several supply control programs versus the cost-effectiveness of selected demand control programs, notably the treatment of cocaine users. That study, using modeling as its primary methodology, concludes that the cost of reducing cocaine consumption by one percent via source-country control[1] would be $783 million per year as compared to a cost of only $34 million per year to accomplish the same reduction via treatment programs. The $783 million figure is 30 to 60 times larger than the cost-effectiveness values of $13 million to $25 million obtained in Chapter IV of this paper.

The measure of effectiveness employed by *Controlling Cocaine* is a reduction in cocaine consumption over a 15-year evaluation period that is equivalent to a reduction of one percent in the present year. This distinction is significant since interdiction and treatment act on different time scales. Interdiction activities produce the bulk of their effects in the first year with perceived or actual supply shortages driving up prices and reducing consumption. Without continuing interdiction efforts, the reduction in consumption levels would reverse in time. On the other hand, treatment programs produce only a small portion of their overall effect in the first year (20 percent as reported in *Controlling Cocaine*). The major effect of treatment is the cumulative effect over the future years of permanently removing users.

In developing the above cost-effectiveness estimates, it was recognized that a wide disparity existed between the empirically derived value and that of the earlier work.

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1 *Controlling Cocaine* uses the term "source-country control." It appears to encompass those activities that have been referred to in this paper as "source-zone interdiction." In this chapter, the terms are used synonymously.

Although the empirical estimate of source-zone cost-effectiveness is admittedly imprecise, it is based on consistent data and sound logic; hence, it can be expected to be accurate in order-of-magnitude if not in detail. Consequently, some attempt to discern assumptions or methodologies employed in *Controlling Cocaine* that might explain the large discrepancy between the two findings is warranted.

The examination here has necessarily been limited in scope in keeping with the restricted counterdrug role of the Department of Defense. The review has primarily focused on key aspects related to the extremes of the findings, *i.e.*, that treatment is 23 times more cost-effective than source-country control in decreasing consumption, which contrasts markedly with this paper's conclusion that a well conceived source-zone interdiction program can equal or exceed the cost-effectiveness of treatment.

Five aspects of the assumptions and methodology employed in *Controlling Cocaine* appear to account for the major differences in conclusions. These are:

1. Use of an inadequate and incomplete model for cocaine supply-control programs that:
   a. Relies on the quantity of product seized and the number of persons arrested as the cost-driving factors, to the exclusion of more important factors.
   b. Assumes weak, nearly linearized, functional dependencies to relate causes and effects, in contradiction to the observed highly nonlinear effects that are consistent with basic economic principles.
2. Assumption of an additive cocaine market pricing structure that is inconsistent with the available data.
3. Use of erroneous results from a demand model as the primary evaluation tool to estimate changes in future cocaine use.
4. Extrapolation of the marginal cost of additional new treatments that is inconsistent with actual treatment experience.
5. Inclusion of inappropriate costs in determining the costs of source-country control and interdiction.

These factors contribute to substantial structural problems with the modeling approach used in earlier research, and are discussed in turn in the rest of this chapter.

A. INADEQUATE AND INCOMPLETE MODEL

The cocaine supply and supply-control models developed in *Controlling Cocaine* focused on seizures as the driver of source country control effectiveness. While the model acknowledges that source country control activities may also produce some indirect increases in financial sanctions and processing costs as seizures increase, the authors contend that these indirect costs constitute a "second-order effect." With this fundamental assumption – that source country interdiction activities can achieve an effect directly or indirectly only through the quantity of coca (or cocaine) seized – it is not surprising that the modeling approach used in *Controlling Cocaine* should find such interdiction activities to be cost-ineffective. The value of the product seized and the costs of replacement are markedly reduced as the distance from the growing areas is reduced; *i.e.*, seizing coca leaf in Peru or Bolivia is not likely to be an effective strategy since coca leaf typically accounts for only a very small portion of the cost of processed cocaine. Since cocaine and cocaine-precursor commodities have little value in the source countries, "routine" seizures of cocaine or cocaine-related materials in these countries have little effect on the market. Routine source zone seizures or loss of physical assets are viewed by the cocaine industry as little more than a nuisance cost of doing business.

Controlling Cocaine modeled the quantity seized as being proportional to the amount of funds expended on source-country control. This is a questionable assumption, as it assumes that all expenditures are of equal value, neglecting the differing effectiveness of alternative strategies, and incorrectly assuming that the objective of source zone expenditures is seizures. The U.S. interdiction strategy in the growing nations is not aimed primarily at seizing product but at significantly disrupting and increasing the costs of production and distribution.

The supply-control model constructed for *Controlling Cocaine* assumes that all costs to producers and to the agencies attempting to control supply are directly related to the quantity of product seized and/or the number of arrests, and, in all cases, the relationship is assumed to be a weak, nearly linear, function. These assumptions are inconsistent with observed events. For example, *Controlling Cocaine* assumes the cost of processing cocaine to be proportional to the quantity of product seized raised to the 0.44 power. This may or may not be correct, but it is irrelevant, since highly nonlinear increases in processing costs can be, and have been, created without significant product seizures. One dramatic example is the DEA raids on the Tranquilandia laboratory complex, which raised the cost of processing chemicals enormously, causing greatly increased cocaine processing costs. During this time, little or no product was seized.

Similar concerns are noted with the modeling of "financial sanctions" as linear functions of product seizures and the number of arrests, in detail (again these may or may not be accurate), while failing to include transshipment costs. In the previous chapter, we pointed out a major example of this mechanism at work by arguing that the direct result of the 1989 war on drugs was the appearance of the Mexican transportation cartels with their associated costs, which increased costs to traffickers enormously within a period of one year during 1989 while seizure of product declined.

A second example of nonlinear effects on transshipment costs is the more recent major disruption of the air transportation network within the growing regions. The coca growing areas of Peru and Bolivia are located in isolated regions with limited to nonexistent established transportation networks. The very remoteness of these areas has provided a major obstacle to host nation efforts to redirect farming to other more socially desirable crops, since such crops are uneconomical for air transport. Coca base has historically been moved from these remote areas to Colombia for processing almost exclusively by small aircraft capable of operating from readily established, small dirt airstrips. This air-based transportation system has become known as the "air bridge." Source zone interdiction strategy has increasingly been aimed at, and has been most effective against, this air bridge.

The recent aggressive actions of the Peruvian Air Force vastly increased the likelihood that a pilot illegally traversing the air bridge would encounter extremely serious consequences. Not surprisingly, such directed efforts drastically increased – by orders-of-magnitude – the "going rate" charged by pilots to transport coca from Peru to Colombia. Carried to the extreme, a successful source zone strategy to interdict the air bridge would totally stop all flights by making the risk unacceptable to pilots. While such an interdiction program would be an overwhelming success, it would be "modeled" as totally ineffective as measured by quantity or assets seized since in such a case the quantity of seizures (or assets or arrests) would be zero. Since *Controlling Cocaine* modeled seizures as proportional to source zone expenditures, that model fails to capture the dramatic effects of Peru's shoot-down policy, since no large increase in expenditures is associated with this change in strategy.

Disrupting the entire transportation system isolates production from its marketplace causing huge inventory back-ups and lowering the value of the product at the source. As a consequence of the air bridge attack of 1995, disruption of air transportation caused the entire coca base production system to operate with significant losses (Figure IV-3) for up to eight months. Farmers growing coca with the expectation of receiving $600/kg for base were forced to sell for only $200/kg – a distinct loss to them. Such nonlinear events are excluded from the model central to *Controlling Cocaine*, but they represent the dominant effects of interdiction, in contrast to the direct losses of seized quantities, equipment losses, and arrests.

Such nonlinear effects are the rule in this economic environment, not the exception. The failure of the *Controlling Cocaine* model to include these dominant nonlinear effects makes the use of such a model problematic and incomplete as an analytical tool.

B. ASSUMPTION OF AN ADDITIVE PRICING STRUCTURE

Appendix A of *Controlling Cocaine* provides the equations used in that study for determining the flow of cocaine product and the establishment of associated prices through a variety of postulated stages in the production/distribution network. As stated in that report:

> The total cost to producers at a given production stage consists of the purchase cost of the net product from the previous stage which provides the input to the current stage..., plus the processing cost of converting that input to gross output, including all capital, labor, and material costs..., plus the cost to producers of supply-control financial sanctions, minus the offsetting revenue from consumption of this stage's product....
>
> ....
>
> The price of the net product from a production stage is the total cost divided by the net product. This equation uses our assumption that each stage of the cocaine supply process is a competitive market.

Implicit in these formulations is the assumption of an additive pricing model, *i.e.*, if a cost is added at an early stage in the supply chain, the absolute value of that cost is added to the follow-on stages. The marginal cost of production for one gram of cocaine is very small, *e.g.*, approximately $1 to $2 per gram, with transportation adding perhaps a few dollars per gram. Hence, under the assumption of an additive model, an increase of significance as measured by a percent increase in the costs of early stages in the supply network would have very little effect on the eventual retail price in the U.S., where a gram of cocaine sells in excess of $100.

As discussed at length in Chapter II, the assumption of an additive pricing structure is in conflict with the data on cocaine prices derived from the *STRIDE* database. Instead, the pricing structure appears to be multiplicative in nature. The assumption of an additive pricing structure, *prima facie*, strongly reduces the likelihood that any action conducted early in the supply/distribution network will be modeled as having substantive impact on prices to cocaine consumers in the U.S.

C. UNRELIABLE ESTIMATES OF PREVALENCE DERIVED FROM THE DEMAND MODEL

Controlling Cocaine used a model of cocaine demand that divides users into two groups, heavy users and light users, based on consumption. These definitions are not identical with, but are close to, those of the National Household Survey on Drug Abuse (NHSDA) "casual users" and "monthly users." *Controlling Cocaine* employs this model as the basis for evaluating, and thus comparing, the manner in which the supply and demand control programs affect the demand for cocaine into the future. The methodology involves a numerical fit to past prevalence data on cocaine use and related cohort retention rate to determine four free parameters of the model. With these four parameters determined, the resulting model was then used to project future use. The values of the four free model parameters used in *Controlling Cocaine* project a flat or increasing trend of cocaine consumption over the period from 1992 to 2000+. This section argues that these parameters were improperly obtained and that a proper determination of these parameters, using the same prevalence data (but ignoring the cohort retention rate) as used by *Controlling Cocaine*, leads to a forecast for future cocaine consumption that is declining. More recent NHSDA data on estimated prevalence are presented that confirm that the trend is decreasing.

The specific demand model used in *Controlling Cocaine* is described in *Modeling the Demand for Cocaine* (Everingham and Rydell, 1994; see also: Everingham *et al.*, 1995). This model assumes that the number of light and heavy users during any year can be represented by a pair of coupled equations with four free parameters that are assumed to be constants over the entire range of years for which the model is applied. This model is used to evaluate usage at yearly intervals, which can then be compared to actual data to fix the values of the four free parameters.

In order to estimate the four parameters of the model, *Modeling the Demand for Cocaine* constrained their allowable range to conform to judgments regarding the reasonableness of such values. There are several "reasonable" but nonetheless questionable assumptions involved in the model and in the constraints placed on the range of parameter values. These are:

1. For simplicity, the model assumes that the parameters are constant over all of the years of interest, despite recognized changes in the popular acceptance of

drugs and in potentially relevant economic conditions over the period of interest.[2] Another unlikely consequence of this assumption is that modeled probabilities for a user leaving any category of usage are independent of how long the user has been in that category.

2. The model assumes that light users progress to become heavy users as a percentage of the number of light users. One might suggest instead that during a time of increasing fascination with drugs, the rate at which light users become heavy users might be driven alternatively (or additionally) to some extent by the number of heavy users. The model restricts this possibility by requiring that all parameters be positive.

3. The model assumes that, over a year's step, no individuals progress from the non-user pool into the heavy user pool.

To find the "best-fit" values of the four parameters, the authors of *Modeling the Demand for Cocaine* employed a trial-and-error search process to arrive at a subjective "good fit." The "good fit" was required to:

1. Produce a "near-minimal" mean square error between the modeled total prevalence and the available prevalence estimates for each of 10 survey years over the period 1972 to 1991.
2. Reproduce the trend and approximately match the fraction of heavy users for the three years (1985, 1988, and 1990) for which data were available.
3. Provide a model value for the "ten-year cohort retention rate" that was close to the "observed value" (actually an average of three reported values).

The rationale for item 3 above, which constitutes an additional constraint on the values of the four coefficients, is unclear. The cohort retention rate cannot be determined from the data presented in *Modeling the Demand for Cocaine*, other than in the average, and the resulting retention rate curves are inconsistent for the three base years of the calculations. It appears that the results are very sensitive to the application of any cohort retention rate constraints, particularly the year chosen to best match with the "observed value." *Modeling the Demand for Cocaine* compromised a good statistical fit to the prevalence data in order to "force" a fit to a questionable retention rate. The very fact that completely different conclusions arise when the last "requirement" is added proves that the assumed underlying model is wrong and/or that some or all of the data are suspect.

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2 Indeed, the cohort retention rate data utilized by *Modeling the Demand for Cocaine*, for three separate years, exhibits strong temporal tendencies in direct contradiction to the assumption of static parameter values.

Figure V-1 displays the fit obtained by *Modeling the Demand for Cocaine* and that obtained in this work using a formal least-squares fitting procedure that estimated the same four parameters in the model of *Modeling the Demand for Cocaine*, but without the cohort retention rate constraint. Both procedures used the identical prevalence and incidence data for the fit.

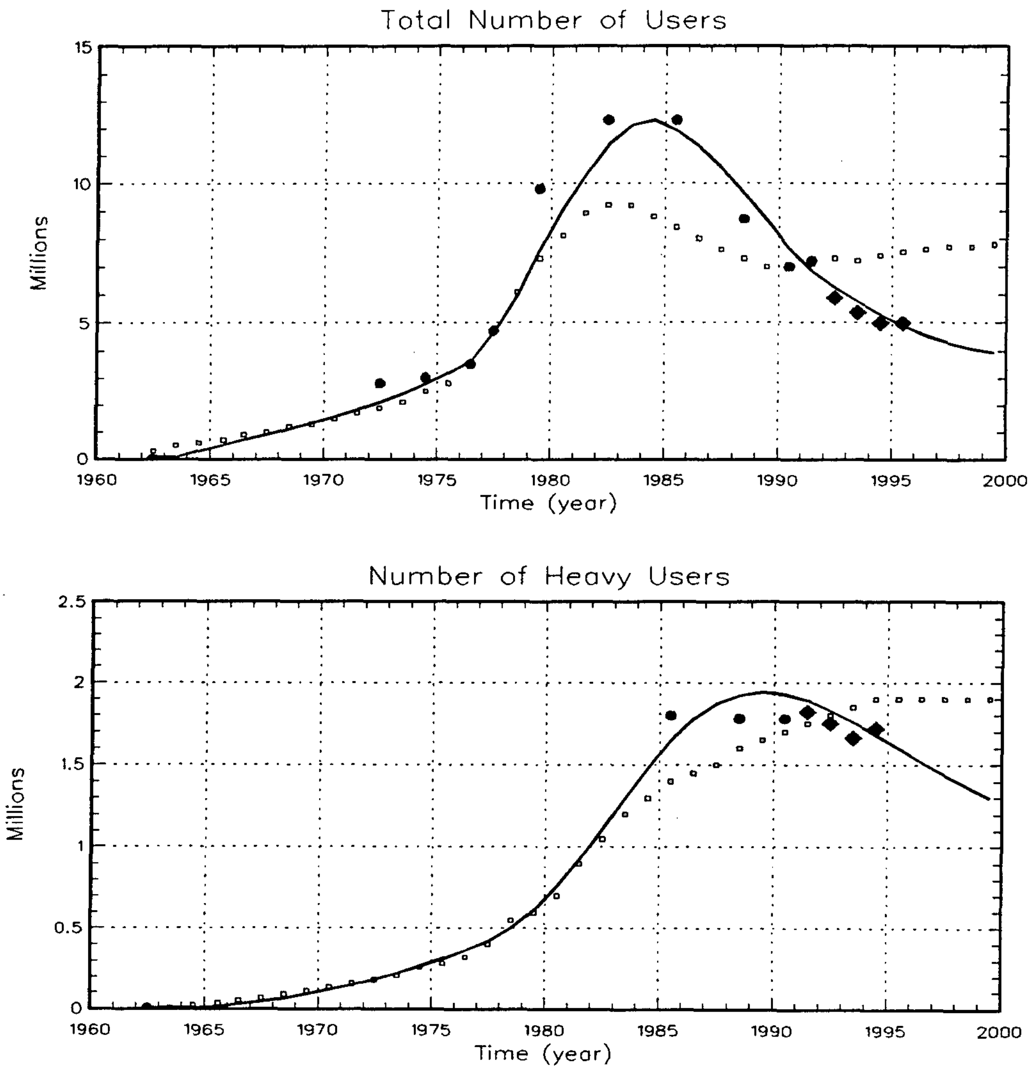

Figure V-1. Result of two fits to the same data for cocaine prevalence (solid symbols). Open squares are the "best fit" results as determined by Everingham and Rydell (1994). The solid line is the "best fit" result of this work.

The figure shows the resultant "best fit" to the total number of cocaine users and the number of heavy users as determined in *Modeling the Demand for Cocaine* (open squares) and the "best-fit" determined in this work (solid line). The solid circles represent the prevalence estimates as determined from the NHSDA. The solid diamond symbols represent recent data that were not available at the time of the original study. These data, which were not considered in either of the fitting procedures, are included to show the predictive ability of the two fits. The new data points for total and heavy use prevalence are those from the NHSDA "past 12 months" and "monthly users" categories scaled to join smoothly with the original data since the NHSDA categories are not exactly the same as those of the original study as defined by Everingham and Rydell (1994.)

Although the formal fit is greatly improved by removal of the cohort retention rate constraint, this fit yields values for the four parameters that no longer seem plausible when these parameters are interpreted as transition probabilities from one state of use to another. A great deal of discussion on the significance of these model parameters and the requirement to use cohort retention rate as a constraint for the model is possible, but is neither warranted nor productive. Clearly, *Controlling Cocaine*'s model (as constrained) fails to describe the trends in the data accurately, especially in the future years. Figure V-1 shows that the "best-fit" to the data as reported in *Modeling the Demand for Cocaine* underestimates (by approximately 30 percent) the total number of cocaine users over the years near the peak of the epidemic (1979 - 1985) and overestimates the number after 1992. Their model is a simple, heuristic one with little or no significance to the transition rates that are used as fitting coefficients; its primary value is in reproducing the functional form of the data. With the removal of the cohort retention rate as a constraint, the model does an excellent job of fitting the original data and predicting "future" trends. This flawed model is still in use today (Rydell, 1996) and is the basis for predicting increasing cocaine use in cocaine control program analyses, despite the fact that survey data since 1992 actually show declining cocaine use.

Since *Controlling Cocaine* and subsequent publications have used this model to determine demand over its 15-year evaluation period, its estimates of cost-effectiveness are affected by the specific values assigned to the four parameters in the model. Most apparent, the parameters interpreted as outflow transition rates from the heavy user category directly affect the estimates of cost-effectiveness of treatment programs and, accordingly, the relative cost-effectiveness advantage cited by *Controlling Cocaine* for treatment as compared to the supply control programs.

D. EXTRAPOLATION OF THE MARGINAL COST OF ADDITIONAL NEW TREATMENTS

Controlling Cocaine found that treatment programs are far more cost-effective than are any of the supply control programs it considered, including source-zone interdiction. Two assumptions appear to have played a major role in determining the cost-effectiveness of treatment programs:

- Assumption 1. The marginal cost of providing additional new treatments would not change from the cost data used in *Controlling Cocaine*.
- Assumption 2. Increased funds directed at treatment programs would be expended solely to increase the treatment of heavy users, that is, those who use cocaine at least weekly, as opposed to light users who use cocaine at least once a year but less than weekly.

Both of these key assumptions are prominently displayed in the Summary of *Controlling Cocaine,* which states:

> The average cocaine treatment ... costs $1,740 per person treated, so $34 million pays for 19,500 treatments. These additional treatments are assumed to be given to heavy cocaine users ... .

Since *Controlling Cocaine* was published in 1994, the amount of funding directed toward treatment programs has increased substantially above inflation. Figure V-2 depicts the funding (squares) for the majority of public treatments (approximately 75 percent) as derived from the Veteran's Administration (VA) and DoHHS (SAMHSA) data, and the number of public treatments (diamonds) actually delivered as extracted from *The National Drug Control Strategy*, 1995 (ONDCP, 1995) and published VA reports (GAO, 1996). Under Assumption 1, the number of treatments from 1989 to 1995 should have increased significantly since an additional billion dollars was made available for treatment over that period. Instead, the actual number of treatments declined by a few percent. A past Director of ONDCP testified before Congress[3] that "between 1988 and 1993, we roughly tripled the treatment budget of the Federal Government," while the "number of people treated per year declined." Since *Controlling Cocaine* assumed private treatments as 35 percent of the total treatments and public treatments as 65 percent of the total (page 88, Table D-1, Note), this analysis has assumed the same ratio. Since the expenditures have

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3 U.S. House of Representatives Report 104-486, "National Drug Policy: A Review of the Status of the Drug War," March 1996.

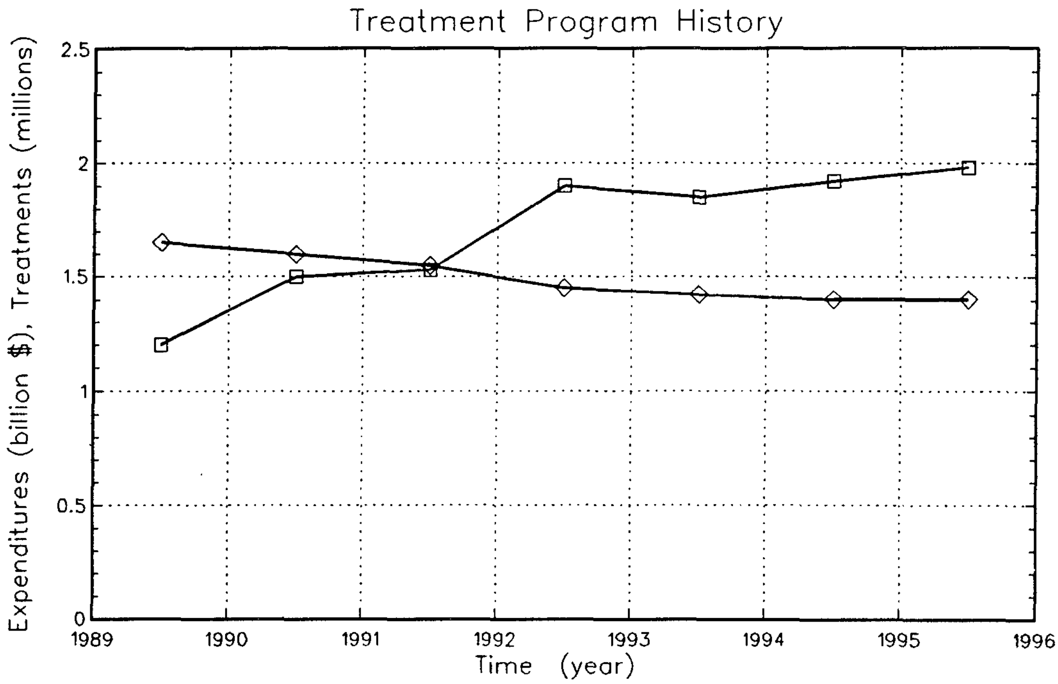

Figure V-2. History of federally-funded drug treatments and funding expenditures. Open squares are treatment expenditures in billions of dollars, open diamonds are number of treatments delivered in millions.

approximately doubled in real terms and the number of treatments have slightly declined, this suggests that the cost reported in *Controlling Cocaine* as $34 million to effect a one percent reduction in consumption over 15 years is low.

Since this paper did not assess the effectiveness of counterdrug programs beyond interdiction, no data relating to Assumption 2 are presented here. Still, it seems likely that some portion of the increased treatment funding has been expended on less-than-heavy users. For example, in determining the proportion of heavy users who stop using cocaine while undergoing treatment, *Controlling Cocaine* relies upon a 1989 study of a number of users who underwent treatment the previous year. The footnote on page 88 of the report states that of this study group, "12.8 percent of those treated were heavy users." In view of the fact that the vast majority of those receiving treatment were not heavy users, it is unlikely that all of the increases in treatment funding have been directed at heavy users. Since it is not apparent that all new expenditures could be targeted only to heavy users, especially with declining user populations (according to the underlying actual data), the reported $34 million to effect a one percent reduction in consumption again appears to be lower than the actual data indicates.

E. INCLUSION OF INAPPROPRIATE COSTS IN DETERMINING THE COSTS OF SOURCE-COUNTRY CONTROL AND INTERDICTION

The determination of cost-effectiveness is significantly affected by the costs determined as appropriate. Significant inconsistencies appear in the numbers adopted as inputs to the cost-effectiveness calculations of *Controlling Cocaine*.

Controlling Cocaine bases its estimates of costs on the funds expended in 1992. In general, *Controlling Cocaine* appears to overestimate costs for source-country control and interdiction, based upon the actual funds expended in 1992 as reported by the ONDCP (1996) report. For example, under the costs for interdiction, *Controlling Cocaine* included state and local assistance provided by DoD ($189 million) and the DoD research and development budget ($91 million). The largest portion of the funds in the DoD R&D budget is for the development of advanced drug detection technologies to support domestic law enforcement and, therefore, these costs should not have been allocated to interdiction. Making these adjustments to the 1992 estimate of interdiction costs reduces the costs for interdiction from the $1.7 billion reported in *Controlling Cocaine* to about $1.5 billion.

Similar problems exist when comparing *Controlling Cocaine's* costs for source-country control. Of particular note:

- ONDCP (1996) reports $161 million for "DEA international" in 1992 while Table B.7 of *Controlling Cocaine* reports $461 million.
- *Controlling Cocaine* includes the costs for the US Agency for International Development (USAID) as part of the costs for source-country control, while offering no argument as to how such humanitarian aid contributes to seizing coca products, trafficker equipment, or arresting drug traffickers, or otherwise directly contributes to the interdiction of the flow of coca products. We believe funds for USAID should not be included as part of the costs for source-country control.
- *Controlling Cocaine* included all costs of the DEA except "domestic enforcement and state and local task forces." This portrays the DEA as something other than a domestic law enforcement agency. *Controlling Cocaine* implicitly charges 90 percent of all data processing costs, all state and local training costs, all administrative costs, all diversion control costs, all research and development costs, *etc*., to source-country control costs. Taking into account that the DEA operates international offices in 42 countries and only Peru, Colombia, and Bolivia are cocaine source nations, it seems unreasonable that 90 percent of the international DEA budget should be allocated to cocaine source-country control as is done in *Controlling Cocaine*.

Making these adjustments and using the data reported for 1992 in ONDCP (1996), source-country control has an approximate cost in 1992 of about $300 million versus the $871 million reported in *Controlling Cocaine*.

F. SUMMARY OF COST-EFFECTIVENESS ESTIMATES

Figure V-3 compares the estimates of cost-effectiveness for three of the four cocaine-control programs presented in *Controlling Cocaine* and those reported in this work. These are source-country control (source-zone interdiction in the terminology of this paper); interdiction (overall); and treatment. This paper attempted no estimate of the cost-effectiveness of domestic enforcement. Figure V-3 indicates significant differences between the estimates of cost-effectiveness presented in *Controlling Cocaine* and those developed in this paper.

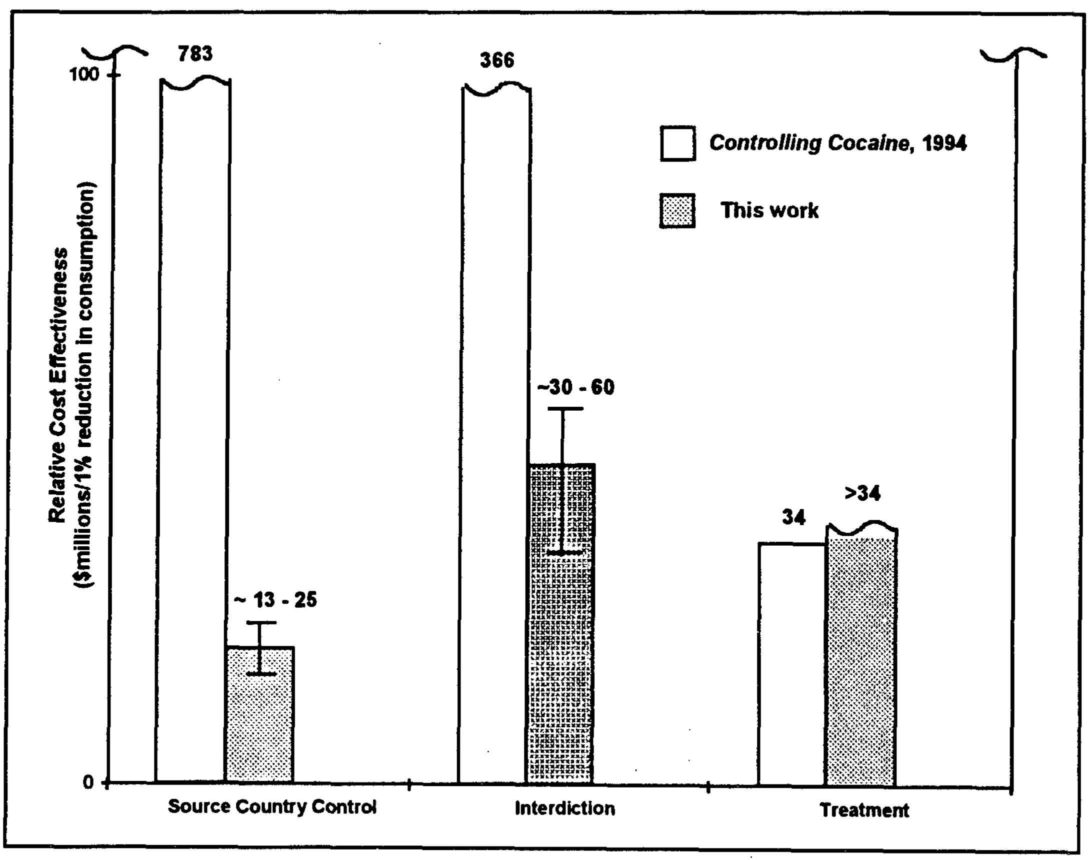

Figure V-3. Comparison of program cost-effectiveness estimates.

In considering the estimates of this paper, the reader is cautioned that:

- The estimate of $13 million to $25 million per year for source-zone interdiction was derived from an estimated expenditure range of $200 million to $400 million per year for the period from 1992 to 1995. It is unlikely that all source zone actions have been equally cost-effective. Nonetheless, this empirical result does suggest that a series of well-conceived source-zone actions can produce supply disruptions resulting in significant increases in the domestic street price of cocaine at relatively modest costs.
- The estimate of $30 million to $60 million per year for the overall interdiction effort is based on a hypothesis that, in the absence of the *War on Drugs*, the street price index would have continued to decline along the trend line evident prior to 1989. While no detailed economic theory that prescribes how the price of a monopolistic or oligopolistic commodity, under the pressure of encroaching competition, approaches equilibrium is presented, the hypothesis is broadly consistent with such theories. Even without this hypothesis, it is still possible to argue, albeit only qualitatively (*e.g.*, from Figures IV-4 and IV-5), that interdiction has caused a significant change in the rate of cocaine price decrease.
- The "IDA estimate" of the cost-effectiveness of treatment is merely a simplistic adjustment to accommodate actual experience regarding the number of treatments provided for the treatment funds expended. The authors of this paper have not studied treatment programs in sufficient detail to assess the accuracy of each of the data presented in the previous study other than to check data sources for the actual experience in order to correct underlying assumptions.

In conclusion, the estimates presented in this paper indicate that each control program reported here has a cost-effectiveness of the same order of magnitude. If each control program is implemented effectively, the two approaches, treatment and interdiction, are complementary — for a given level of funding, interdiction can have a significant immediate response that largely vanishes when funding is terminated,[4] while treatment, with only a small initial response, has effects that persist even after funding is terminated. Both approaches will fail to have a permanent effect when funding is terminated if the incidence rate is not reduced through other processes (*e.g.*, education). Ultimately, this analysis argues for a balanced approach to drug control that includes interdiction, treatment, and incidence reduction programs.

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4 To the degree that interdiction increases the price of cocaine, it also causes some reduction in incidence. These incidence reductions have a persisting effect over time.

CHAPTER VI

FINDINGS

VI. FINDINGS

Based upon the data and analysis presented in this paper, the following are IDA's three principal findings:

1. Well-conceived source-zone operations, in cooperation with host nation forces, that significantly and unexpectedly disrupt the normal drug trafficker processes for producing and transporting coca products from the source zone, cause discernible increases in the street price of cocaine in the U.S., and, through normal market relationships between price and demand, thereby reduce cocaine consumption.

2. Significant source-zone interdiction activities can produce a lasting increase in the street price of cocaine in the U.S. resulting from higher costs of transshipment.

3. Supply disruptions have significant effects on the street price of cocaine. Most other policy studies to date have assumed an "additive" structure and weak price effects; these assumptions are questionable on both empirical and theoretical grounds.

Additional relevant findings are:

4. Despite previously published reports based on models of demand that reflect continuing increases, improved modeling and additional data both indicate that the total number of cocaine users has been declining since approximately 1985.

5. When the supply of cocaine to the market is obstructed, traffickers respond by reducing the purity of the cocaine sold in the U.S. in an apparent attempt to supply customers at prices close to the customary price per dose.

6. *STRIDE* data can be used in combination with robust analysis techniques to assess the effectiveness of supply control activities and to provide feedback useful to those executing such activities.

7. The low cost effectiveness of interdiction as contrasted to the cost effectiveness of demand control, as previously reported in *Controlling Cocaine*, is inconsistent with the available data.

8. Several indirect, but nonetheless logical, indicators of cocaine usage show clear inverse correlation with *STRIDE* price excursions.

These findings in no way suggest that any particular element of supply or demand control is not a valuable component of a comprehensive strategy to counter drug use. Rather, they demonstrate that the vast differences of cost-effectiveness concluded by earlier work are not supported by the currently available data. Ultimately, our analysis argues for a balanced approach to drug control that would include interdiction, treatment, and incidence reduction programs.

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APPENDIX A

ACRONYMS

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LIST OF ACRONYMS

AF	Air Force
ARPA	Advanced Research Project Agency
DAWN	Drug Abuse Warning Network
DEA	Drug Enforcement Administration
DoD	Department of Defense
DoHHS	Department of Health and Human Services
DUF	Drug Usage Forecast
GAO	General Accounting Office
IDA	Institute for Defense Analyses
NHSDA	National Household Survey on Drug Abuse
ONDCP	Office of National Drug Control Policy
PEAH	Projecto Especial Alto Huallaga
SAMHSA	Substance Abuse and Mental Health Services Admistration
SBCL	SmithKline Beecham Clinical Laboratories
SJ	Support Justice
STRIDE	System to Retrieve Information from Drug Evidence
TAT	Tactical Assessment Team
TEDS	Treatment Episode Data Set
TIC	The Interdiction Committee
U.S.	United States
UNDCP	United Nations Drug Control Program
USAID	US Agency for International Development
USIC	U.S. Interdiction Coordinator
MT	Metric Ton

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Analysis of cocaine street prices since 1985, intelligence data regarding cocaine base movement in the Andean nations of South America, and cocaine usage indicators are used to arrive at the conclusion that a source zone interdiction strategy to disrupt significantly the production/transportation of coca base is a cost-effective operational strategy for increasing cocaine prices, and thereby for reducing cocaine use in the United States. Empirical evidence supporting the correlation of source zone interdiction effectiveness with the price of cocaine in the United States is presented, arguing that specific source zone operations since 1989 have directly affected cocaine markets, resulting in price increases as large as 100 percent.

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