Measuring Heroin Availability in Three Cities

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Office of National Drug Control Policy
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RAND

Controlling Cocaine

Supply Versus Demand Programs

C. Peter Rydell
Susan S. Everingham

DRUG POLICY RESEARCH CENTER

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Prepared for the Office of
National Drug Control Policy
United States Army

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PREFACE

This report presents a model-based policy analysis of alternative methods of controlling cocaine use in the United States. It builds upon previous and parallel work at RAND and elsewhere on cocaine supply and cocaine demand. In particular:

- Reuter, Peter, and Mark Kleiman (1986), "Risks and Prices: An Economic Analysis of Drug Enforcement," in *Crime and Justice: A Review of Research*, Norval Morris and Michael Tonry (eds.), Chicago: University of Chicago Press.
- Crawford, Gordon B., and Peter Reuter (1988), *Simulation of Adaptive Response: A Model of Drug Interdiction*, N-2680-USDP, Santa Monica, CA: RAND.
- Homer, Jack B. (1990), *A System Dynamics Simulation Model of Cocaine Prevalence*, Los Angeles, CA: UCLA Drug Abuse Research Group.
- Dombey-Moore, Bonnie, and Susan Resetar (1994), *A System Description of the Cocaine Trade*, MR-236-A/AF/DPRC, Santa Monica, CA: RAND.
- Kennedy, Michael, Peter Reuter, and Kevin Jack Riley (1994), *A Simple Economic Model of Cocaine Production*, MR-201-USDP, Santa Monica, CA: RAND.
- Everingham, Susan S., and C. Peter Rydell (1994), *Modeling the Demand for Cocaine*, MR-332-ONDCP/A/DPRC, Santa Monica, CA: RAND.

With that other work as a foundation, this study focuses on ways to intervene in the supply and demand processes to mitigate the cocaine problem.

This analysis examines only cocaine-control programs. That is a sufficiently ambitious undertaking, given the current state of the art of cost-effectiveness analyses of drug-control policies. However, the analytical methods used here are relevant to analyses of control programs for other illicit drugs, such as heroin and marijuana. Moreover, the programmatic conclusions of this study are likely to have analogues in those other drug-control efforts.

The work reported here was sponsored by the Office of National Drug Control Policy, the U.S. Army, RAND's Drug Policy Research Center (DPRC) with funding from The Ford Foundation, and RAND's Social Policy Department. The research was jointly carried out within three RAND entities: the DPRC, the National Defense Research Institute (NDRI), and the Strategy and Doctrine Program of the Arroyo Center. NDRI is a federally funded research and development center that supports the Office of the

Secretary of Defense, the Joint Staff, and the defense agencies. The Arroyo Center is the U.S. Army's federally funded research and development center.

CONTENTS

Preface iii

Figures vii

Tables ix

Summary xi

Acknowledgments xxi

Glossary of Variables xxiii

Chapter One
- INTRODUCTION 1
- The Size of the Problem 1
- Cocaine-Control Programs 4
- The Model 7
- Overview of the Report 8

Chapter Two
- SUPPLY CONTROL 9
- How Supply-Control Programs Work 10
- Effects on Cocaine Consumption 11

Chapter Three
- DEMAND CONTROL 17
- Consumption of Cocaine 17
- Characteristics of Treatment Programs 19
- Effects on Cocaine Consumption 23

Chapter Four
- SENSITIVITY TO KEY PARAMETERS 29
- Parameters Analyzed 29
- Uncertainty Ranges 30
- Sensitivity Results 30
- Interaction Effects 31
- Threshold Analysis 32

Chapter Five
- ALTERNATIVE EVALUATION CRITERIA 35
- Number of Cocaine Users 36

Societal Costs 36
How Large Are the Societal Costs of Cocaine? 37
How Do Control Programs Affect the Societal Costs? 39

Chapter Six
COMPOSITE PROGRAMS 43

Appendix
A. COCAINE SUPPLY 51
B. SUPPLY-CONTROL PROGRAMS 61
C. COCAINE DEMAND 73
D. DEMAND-CONTROL PROGRAMS 83
E. THE COCAINE-CONTROL MODEL 93
F. SENSITIVITY TO UNCERTAIN PARAMETERS 105

References 113

FIGURES

S.1. Cocaine Consumption, by Type of User: 1972–1992 xi
S.2. Distribution of Annual Expenditure on Cocaine Control: 1992 xiii
S.3. Cost of Decreasing Cocaine Consumption by 1 Percent with Alternative Cocaine-Control Programs xiv
S.4. Cost of Domestic Enforcement Relative to Treatment, for 1 Percent Reductions in Alternative Evaluation Criteria xv
S.5. Savings in Societal Costs of Crime and Lost Productivity Due to Cocaine Use per Dollar Spent on a Control Program xvii
S.6. Cocaine-Control Budget vs. Cocaine Consumption xvii
S.7. Dynamics of Change in Cocaine Consumption xix
1.1. Number of Cocaine Users, by Intensity of Use 2
1.2. Cocaine Consumption, by Type of User 2
1.3. Expenditure on Cocaine, by Users 3
1.4. Price of Cocaine: 1977–1992 4
1.5. Distribution of Annual Expenditures on Cocaine Control: 1992 5
1.6. Alternative Control Programs 6
2.1. Cocaine Supply Flows 9
2.2. Cocaine Production: 1992 10
2.3. Cost of Cocaine Production: 1992 11
2.4. Price of Net Product, by Production Stage: 1992 12
2.5. Proportion of Consumption Reduction Caused by Separate Supply-Control Effects 13
2.6. Cost of Reducing Consumption by 1 Percent with Alternative Supply-Control Programs 14
3.1. Light and Heavy Cocaine Users, by Location: 1992 17
3.2. Cocaine Users vs. Total Consumption: 1990 18
3.3. Annual Dynamics of Cocaine Use 19
3.4. Number of Treatments per Year, by Treatment Duration 21
3.5. Cost per Treatment Accession 22
3.6. Additional Outflow from Heavy Use Due to Treatment 22
3.7. Proportion of Consumption Reduction Caused by Separate Treatment Effects 23
3.8. Cost of Reducing Cocaine Consumption by 1 Percent with Alternative Cocaine-Control Programs 25
3.9. Dynamics of Consumption Change if $250 Million is Added to Each Program's Annual Budget 27

4.1. Effect of Price Elasticity of Demand on Cost of Achieving a 1 Percent Reduction in Consumption 33
4.2. Effect of Additional Outflow Due to Treatment on Cost of Achieving a 1 Percent Reduction in Consumption 33
4.3. Threshold Values of Price Elasticity and Additional Outflow, Where Domestic Enforcement Becomes More Cost-Effective Than Treatment 34
5.1. Costs of Reducing Users by 1 Percent vs. Costs of Reducing Consumption by 1 Percent 37
5.2. Costs of Reducing Societal Costs by 1 Percent vs. Costs of Reducing Consumption by 1 Percent 40
5.3. Cost of Domestic Enforcement Relative to Treatment Under Alternative Evaluation Criteria 41
5.4. Savings in Societal Costs Resulting from Alternative Control Programs 41
6.1. Effect of Alternative Composite Programs on Cocaine Consumption 45
6.2. Continuous Range of Alternatives to Current Cocaine-Control Policy 46
6.3. Dynamics of Changes in Cocaine Consumption 47
6.4. Dynamics of Consumption Change Under Alternative D (100 Percent Treatment, No Cut in Supply-Control Budget) 48
6.5. Effect of Composite Cocaine-Control Programs on Total Societal Cost 49
C.1. Incidence Scenarios 79
C.2. Consumption Projections 80
C.3. Estimated Demand Response to Price for Cigarettes and Alcohol 80
E.1. Logical Structure of Cocaine-Control Model 93
E.2. How Cocaine-Control Programs Work 94
E.3. Spreadsheet Implementation of Cocaine-Control Model 98
E.4. Input of Key Parameters 99
E.5. Inputs to Supply Model 99
E.6. Inputs to Demand Model 100
E.7. Inputs for Specific Projection Year 101
E.8. Supply Model 101
E.9. Demand Model 102
E.10. Outputs 103
F.1. Tornado Diagram Ranking the Degree to Which Uncertainty in Key Parameters Affects Relative Program Cost 109
F.2. Threshold Values of Price Elasticity and Additional Outflow, Where Domestic Enforcement Becomes More Cost-Effective Than Treatment 112

TABLES

S.1. Comparison of Alternative Composite Cocaine-Control Programs xviii
2.1. Effect of Supply-Control Programs on Cocaine Consumption 14
3.1. Treatment Program Characteristics 20
3.2. Effect of Control Programs on Cocaine Consumption 24
3.3. Other Consequences of Additional Control that Reduces Cocaine Consumption by 1 Percent 26
4.1. Ranges for Sensitivity Analysis 30
4.2. Cost of Reducing Consumption by 1 Percent: Effect of Price Elasticity of Demand 30
4.3. Cost of Reducing Consumption by 1 Percent: Effect of Additional Outflow Due to Treatment 31
4.4. Effect of Joint Variation of Parameters 32
5.1. Effect of Control Programs on Number of Cocaine Users 36
5.2. Estimates of Annual Crime and Lost-Productivity Costs Due to Cocaine Use 38
5.3. Effect of Control Programs on Cost of Crime and Lost Productivity 39
6.1. Characteristics of Alternative Composite Plans 44
6.2. Results of Alternative Composite Plans 48
A.1. Source-Country Coca Leaf Production: 1992 54
A.2. Production of Coca Leaf: 1992 55
A.3. Conversion of Coca Leaf to Coca Paste: 1992 55
A.4. Conversion of Coca Paste to Cocaine Base: 1992 56
A.5. Conversion of Cocaine Base to Cocaine Wholesale in Source Country: 1992 56
A.6. Summary of Source-Country Production of Cocaine for the United States Market: 1992 57
A.7. Transportation of Cocaine to the United States: 1992 58
A.8. Retailing Cocaine in the United States: 1992 58
A.9. Derivation of the Retail Price of Cocaine 59
B.1. Source-Country Seizures and Arrests: 1992 66
B.2. Total Arrests for Drug Abuse Violations: United States, 1986–1991 67
B.3. Arrests for Sale or Manufacture of Drugs: United States, 1991 67
B.4. Arrests of Cocaine Dealers and Agents: 1992 67

B.5. Seizures of Cocaine: 1992 68
B.6. Seizures of Cocaine-Production Assets: 1992 68
B.7. Agency Budgets for Cocaine Control 69
B.8. Total Cocaine Supply-Control Expenditure: 1992 70
B.9. Annual Agency Budgets, Arrests, and Asset Seizures per Metric Ton of Cocaine Seized 70
B.10. Financial Sanctions Imposed on Producers of Cocaine: 1992 71
C.1. Cocaine Consumption by Type of User: 1992 77
C.2. Dynamics of Cocaine Demand 78
D.1. Number of Cocaine Treatments: 1989 and 1992 88
D.2. Characteristics of Cocaine Treatment Programs: 1992 89
D.3. Effectiveness of Treating Heavy Cocaine Users: Outpatient Treatment 90
D.4. Effectiveness of Treating Heavy Cocaine Users: Residential Treatment 91
E.1. Estimates of the Price Elasticity of Supply 96
F.1. Ranges for Sensitivity Analysis 107
F.2. Cost of Reducing Consumption by 1 Percent: Effect of Price Elasticity of Demand 107
F.3. Cost of Reducing Consumption by 1 Percent: Effect of Additional Outflow Due to Treatment 107
F.4. Cost of Reducing Consumption by 1 Percent: Effect of Processing Cost Elasticity 108
F.5. Cost of Reducing Consumption by 1 Percent: Effect of Marginal/Average Productivity 108
F.6. Cost of Reducing Consumption by 1 Percent: Effect of Proportion Relative Costing of Seizures 108
F.7. Cost of Reducing Consumption by 1 Percent: Effect of High-Proportion Residential Treatments 108
F.8. Cost of Reducing Consumption by 1 Percent: Effect of Real Discount Rate 109
F.9. Joint Effect of Parameters on Cost of Domestic Enforcement Relative to Treatment 110

The current cocaine epidemic in the United States started in the late 1960s, picked up momentum during the 1970s, and is still going strong in the 1990s. The number of cocaine users peaked in the early 1980s at about 9 million, and has gradually decreased to a little more than 7 million today. However, that downward trend in the total number of users is misleading, because a decline in the number of light users has masked an increase in the number of heavy users.[1]

Heavy users consume cocaine at a rate approximately eight times that of light users, so the upward trend in consumption by heavy users roughly cancels the downward trend in consumption by light users. The result is that total consumption of cocaine in the United States has remained at its mid-1980s peak for almost a decade (see Figure S.1).

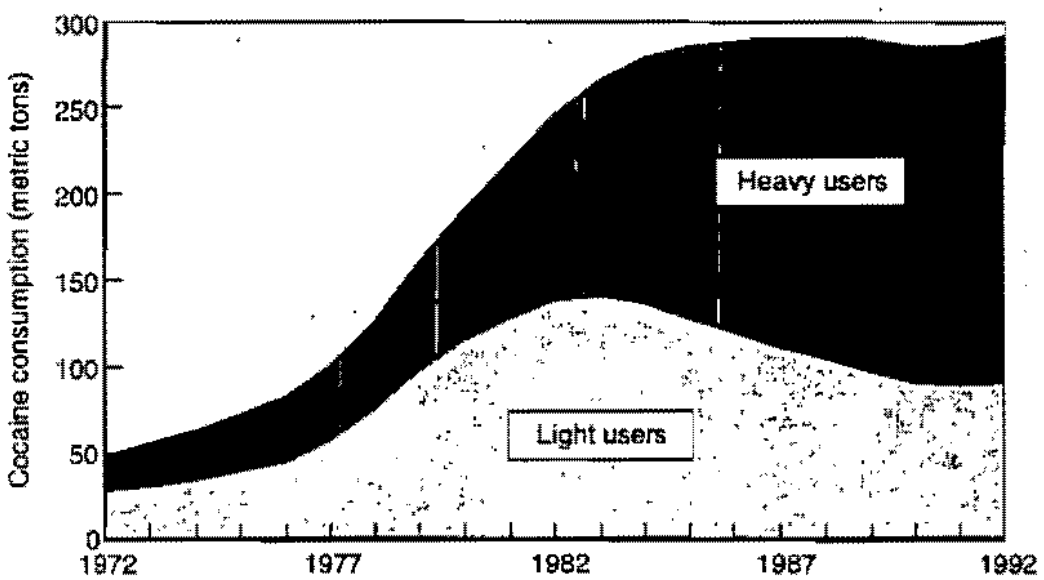

Figure S.1—Cocaine Consumption, by Type of User: 1972–1992

[1]This analysis defines "heavy use" as once a week or more and "light use" as at least once a year, but less than weekly. At the end of 1992, there were an estimated 5.6 million light users and 1.7 million heavy users, by these definitions.

The persistence of high levels of cocaine consumption indicates the magnitude of the cocaine problem and the need for government to think carefully about its response. Part of thinking carefully includes estimating the relative cost-effectiveness of various available interventions. Four such interventions analyzed in this report are:

- **Source-country control:** coca leaf eradication; seizures of coca base, cocaine paste, and the final cocaine product in the source countries (primarily Peru, Bolivia, and Colombia).
- **Interdiction:** cocaine seizures and asset seizures by the U.S Customs Service, the U.S. Coast Guard, the U.S. Army, and the Immigration and Naturalization Service (INS).
- **Domestic enforcement:** cocaine seizures, asset seizures, and arrests of drug dealers and their agents by federal, state, and local law enforcement agencies; imprisonment of convicted drug dealers and their agents.
- **Treatment of heavy users:** outpatient and residential treatment programs.

This study analyzes the relative and, to a lesser extent, absolute cost-effectiveness of these programs. The first three programs focus on "supply-control." They raise the cost to dealers of supplying cocaine by seizing drugs and assets, and by arresting and incarcerating dealers and their agents. The increased production costs raise retail cocaine prices and thus reduce consumption, partly by discouraging current consumption and partly by modifying the flows of people into and out of cocaine use, so that the number of cocaine users gradually declines.

The fourth program is a "demand-control" program: It reduces consumption directly, without going through the price mechanism. Treatment reduces consumption in the short term, because most clients stop their cocaine use while in the program, and in the longer term, because some clients stay off heavy drug use even after treatment ends.

User sanctions (arresting and incarcerating people for using drugs) and drug-abuse prevention programs (both school-based and community-based) are also viable interventions, but analyzing them is beyond the scope of the present study.

To assess the cost-effectiveness of these programs, one needs to know (1) how much is being spent on them and (2) what benefits accrue from that spending. Determining current spending levels, although time-consuming in practice, is conceptually straightforward.

Currently, an estimated $13 billion is being spent in the United States each year on the four cocaine-control programs listed above. The bulk of these resources goes to domestic enforcement—drug busts, jails, and prisons are expensive. Treatment accounts for only a 7 percent share of this expenditure, even when privately funded treatment is included (see Figure S.2).

Measuring the benefits of the four programs is more difficult, in part because they produce disparate effects. Supply-control programs generate cocaine seizures, asset seizures, and arrest and imprisonment of drug dealers. Treatment programs induce

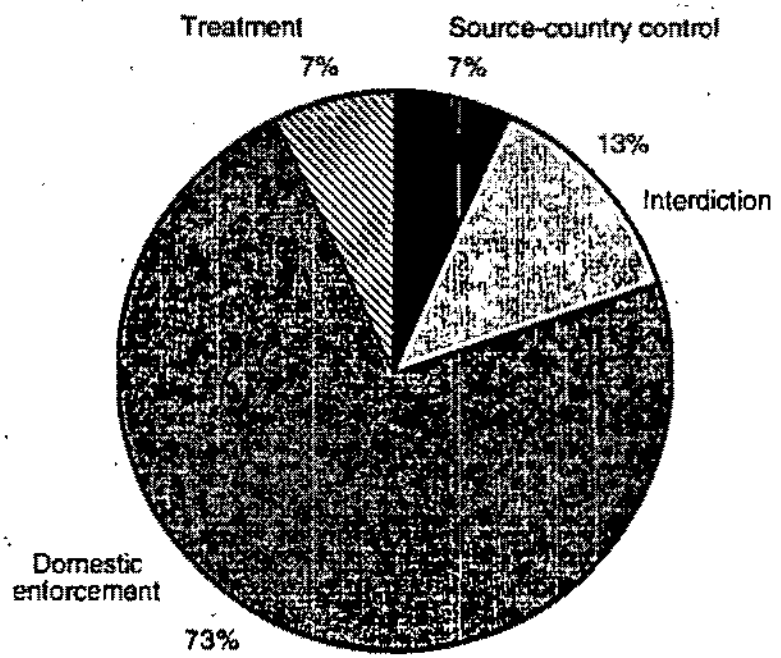

Figure S.2—Distribution of Annual Expenditure on Cocaine Control: 1992

people to stop using cocaine. These outcome measures cannot be directly compared; they must first be translated into a common measure of effectiveness. For much of this analysis, the common measure used is the cost of a given reduction in U.S. consumption of cocaine.

The analytical goal is to make the discounted sum of cocaine reductions over 15 years equal to 1 percent of current annual consumption. The most cost-effective program is the one that achieves this goal for the least additional control-program expenditure in the first projection year. The additional spending required to achieve the specified consumption reduction is $783 million for source-country control, $366 million for interdiction, $246 million for domestic enforcement, or $34 million for treatment (see Figure S.3). The least costly supply-control program (domestic enforcement) costs 7.3 times as much as treatment to achieve the same consumption reduction.

The short story behind the supply-control cost estimates is that money spent on supply-control programs increases the cost to producers of supplying the cocaine. Supply costs increase as producers replace seized product and assets, compensate drug traffickers for the risk of arrest and imprisonment, and devote resources to avoiding the seizures and arrests. These added costs get passed along to the consumer as price increases, which in turn decreases consumption.

For example, a $246 million additional annual expenditure on domestic enforcement causes annual cocaine supply costs to increase by an estimated $750 million, or 2 percent of the estimated $37.6 billion spent annually by consumers on cocaine. As-

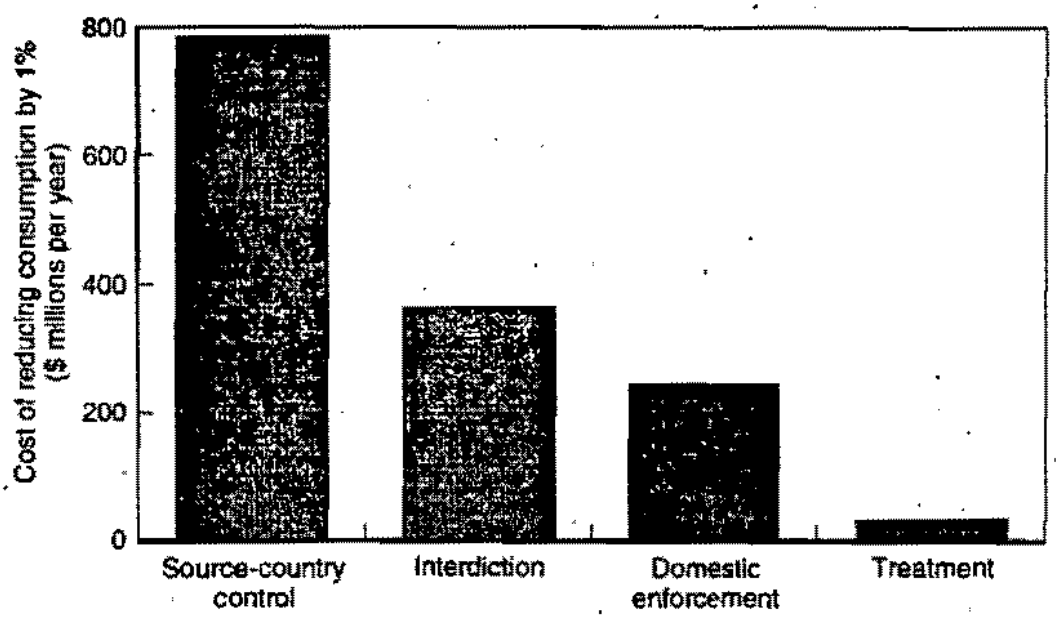

Figure S.3—Cost of Decreasing Cocaine Consumption by 1 Percent with Alternative Cocaine-Control Programs

suming that the percentage decrease in consumption caused by a price increase is half the percentage price increase, the additional control expenditure achieves the goal of reducing consumption by 1 percent.

The specific cost estimates for the supply-control programs are, of course, driven by the assumption that a 1 percent increase in price causes a 0.5 percent decrease in cocaine consumption. (Some of this consumption decrease occurs immediately as this year's price increase reduces current consumption; the rest occurs gradually over time as the price increase alters flows of people into and out of cocaine use.) If the consumption decrease caused by a price increase is large, the costs of achieving the specified consumption reduction with supply-control programs will be proportionately small. However, the finding that treatment programs are more cost-effective than enforcement programs is not in question, because the effect of price on consumption would have to be 7 times the assumed level to alter that conclusion.

The estimate that an additional $34 million dollars spent on cocaine treatment would reduce cocaine consumption by 1 percent is based on two factors: (1) most users stay off drugs while in treatment, and (2) some users stay off drugs after treatment.

The average cocaine treatment (a mixture of relatively inexpensive outpatient and relatively expensive residential treatments, including partial as well as complete treatments) 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 (of whom there are about 1.7 million today) with average use of about 120 grams of cocaine a year. The average treatment lasts 0.3 years, and 80 percent of people in treatment are off drugs, so the in-treatment effect of 19,500 treatments is about 5,000

person-years less heavy cocaine use, which amounts to 0.6 metric tons less cocaine consumption.

An estimated 13 percent of heavy users treated do not return to heavy use after treatment. Although not all those departures are permanent, during the 14 years following treatment, the 19,500 treatments would generate an estimated present value of 20,000 person-years less heavy cocaine use, which amounts to 2.4 metric tons less cocaine consumption. If we add the 0.6 metric ton in-treatment reduction to the 2.4 metric ton after-treatment reduction, we find that 19,500 additional treatments would reduce cocaine consumption by an amount equal to 1 percent of the 300 metric tons currently consumed annually.

The *specific* cost advantage of treatment over enforcement ($34 million as opposed to $246 million for domestic enforcement to achieve the same benefit) depends crucially on the estimated after-treatment effect. However, the cost advantage is so large that even if the after-treatment effect is ignored, treatment still is more cost-effective than enforcement. The in-treatment effect is one-fifth of the total, and five times $34 million is still less than $246 million.

Reducing the quantity of cocaine consumed is not the only possible measure of program effectiveness. However, our findings about the relative cost-effectiveness of the different control programs do not depend upon the choice of evaluation criteria. The cost-effectiveness ranking of the control programs studied here is the same whether one evaluates the programs in terms of their effects on consumption, the number of users, or societal costs of crime and lost productivity due to cocaine use. That is, in all cases, the supply-control programs are more costly than treatment programs per unit accomplishment (see Figure S.4).

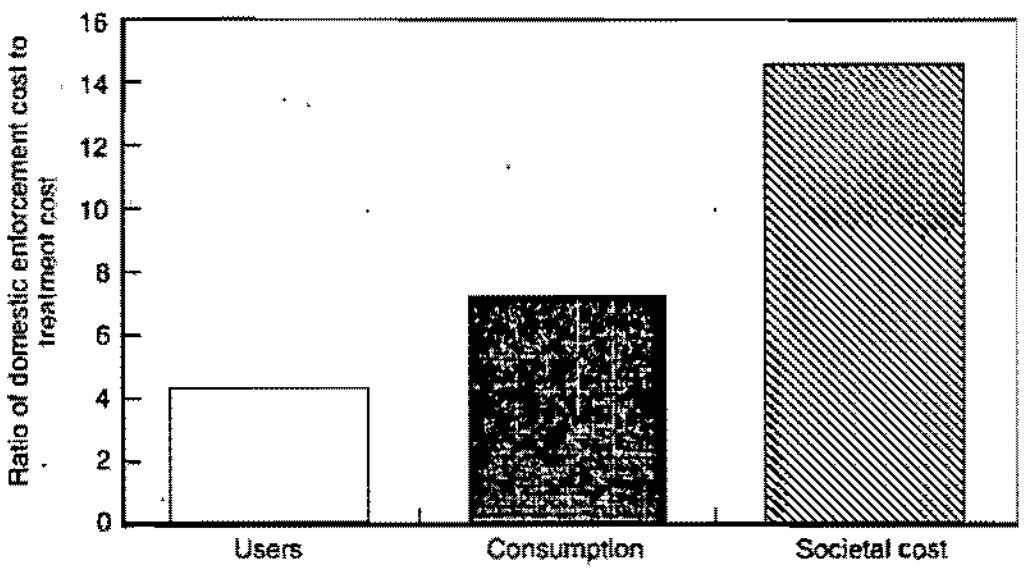

Figure S.4—Cost of Domestic Enforcement Relative to Treatment, for 1 Percent Reductions in Alternative Evaluation Criteria

The extent to which supply-control measures are more expensive, however, does vary depending on the evaluation measure chosen. Domestic enforcement costs 4 times as much as treatment for a given amount of user reduction, 7 times as much for consumption reduction, and 15 times as much for societal cost reduction.

These results suggest that if an additional dollar is going to be spent on drug control, it should be spent on treatment, not on a supply-control program. They do not, however, indicate whether or not that dollar should be spent in the first place. It might be that all four programs generate greater benefits than they cost, and treatment is just the best of four good programs. Or, at the other extreme, treatment might be merely the least ineffective of four ineffective programs.

With the first two criteria, quantity of cocaine consumed and number of users, this is as specific as one can get without placing a figure on the dollar value of reducing U.S. cocaine consumption by 1 metric ton or the number of users by 1,000. The benefits under the third criterion, reductions in the societal cost of crime and lost productivity, are, however, already measured in dollars. Hence, using this criterion, we can make some estimates of the four programs' absolute cost-effectiveness. The reader is cautioned, however, that societal costs are difficult to define, let alone measure; thus our estimates are very rough. Nevertheless, the results are intriguing.

This study found that the savings of supply-control programs are smaller than the control costs (an estimated 15 cents on the dollar for source-country control, 32 cents on the dollar for interdiction, and 52 cents on the dollar for domestic enforcement). In contrast, the savings of treatment programs are larger than the control costs; we estimate that the costs of crime and lost productivity are reduced by $7.46 for every dollar spent on treatment (see Figure S.5).

Our findings thus suggest a way to make cocaine control policy more cost-effective: Cut back on supply control and expand treatment of heavy users. In light of this conclusion, four (prominent) alternatives to current policy are explored this study:

- Alternative A: decrease each of the three supply-control program budgets by 25 percent.
- Alternative B: decrease the supply-control budgets by 25 percent and double the current treatment budget.
- Alternative C: decrease the supply-control budgets by 25 percent and treat 100 percent of heavy users each year.
- Alternative D: treat 100 percent of heavy users each year without changing the supply-control budget.

Our best estimates of the consequences of pursuing these alternatives to current policy are summarized in Figure S.6 and Table S.1. If supply-control budgets are cut by 25 percent (Alternative A), the cocaine problem (as measured by consumption) gets worse, but the supply-control cuts make the overall control budget decrease. However, spending about half of the supply-control savings on doubling treatment (Alternative B) reduces cocaine consumption below what would occur under current

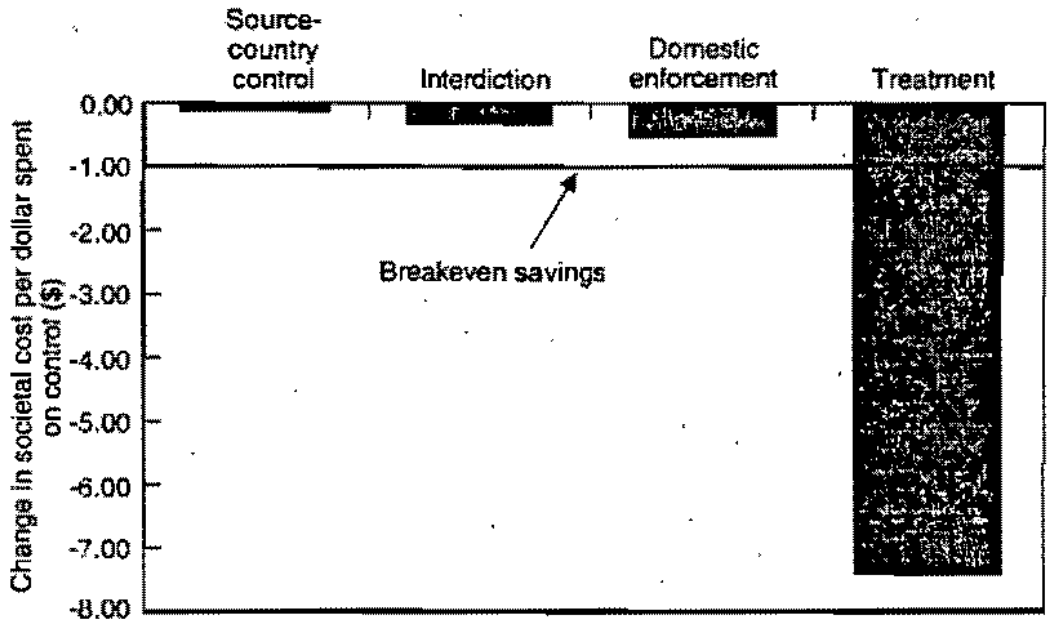

Figure S.5—Savings in Societal Costs of Crime and Lost Productivity Due to Cocaine Use per Dollar Spent on a Control Program

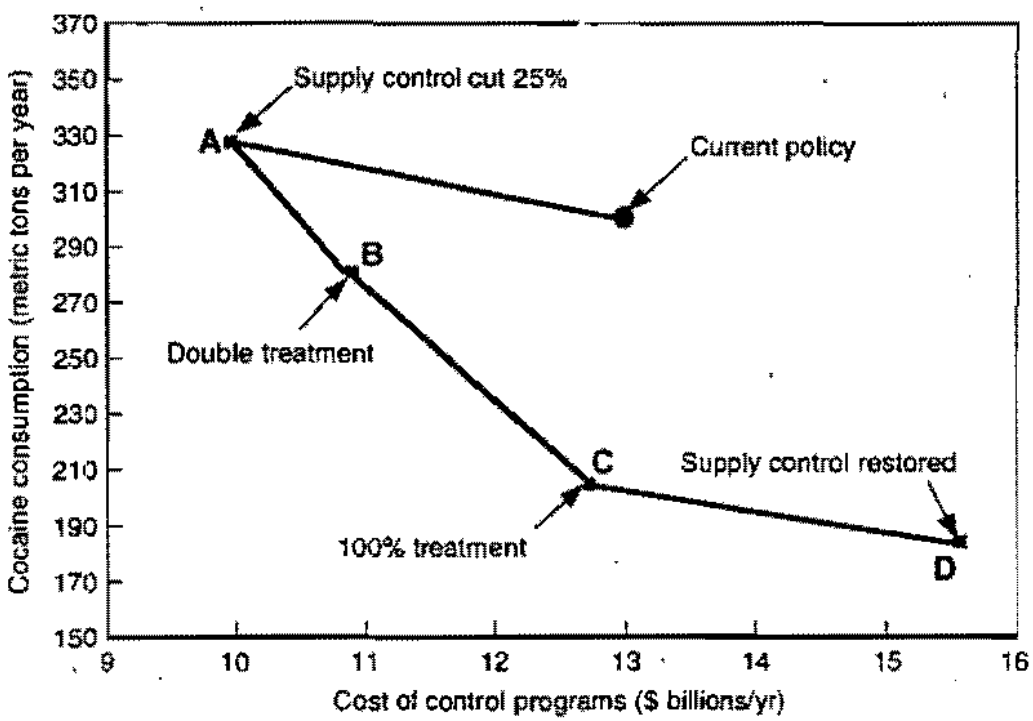

Figure S.6—Cocaine-Control Budget vs. Cocaine Consumption

Table S.1

Comparison of Alternative Composite Cocaine-Control Programs

Intervention Strategy	Total Control Cost ($ billions/yr)	Evaluation Criterion: Users (millions)	Consumption (metric tons/yr)	Societal Costs[a] ($ billions/yr)	Societal Cost plus Control Costs ($ billions/yr)
Current policy	13.0	7.06	314	29.0	42.0
Alternative A: Supply control – 25%	10.0	7.28	344	30.0	40.0
Alternative B: Double treatment	10.9	7.06	294	25.8	36.7
Alternative C: 100% treatment	12.7	6.67	211	19.0	31.7
Alternative D: Restore supply ctrl	15.6	6.42	186	18.3	33.9

NOTE: Alternative A cuts all three supply-control program budgets by 25 percent; Alternative B spends one-third of the supply-control savings on doubling the current treatment budget; Alternative C spends nearly all the supply-control savings to treat 100 percent of the heavy users each year; and Alternative D treats 100 percent of the heavy users each year with no cut in the supply-control budget. Estimates are annualized values over 15 projection years using a 4 percent real discount rate.

[a]Estimated cost of crime and lost productivity due to cocaine use.

policy. Expanding treatment to all heavy users (Alternative C) further reduces consumption and uses up essentially all the savings from the supply-control cut. Finally, if all heavy users are treated and the supply-control budget is not cut (Alternative D), consumption decreases even more, but the control budget is one-fifth higher than it is under current policy.

Decreasing supply control by 25 percent and doubling treatment (Alternative B) would leave the number of users essentially unchanged but would decrease average annual consumption by 20 metric tons (a 6 percent reduction). This composite program would save $2.1 billion in annual costs of cocaine control and $3.2 billion in annual societal costs, for a total annual saving of $5.3 billion.

Further expanding treatment to cover all heavy users (Alternative C) would decrease the number of users by 0.39 million and decrease average annual consumption by 103 metric tons, relative to current policy. The total annual cost of cocaine control would be only $0.3 billion less than under current policy, but societal costs would decrease by $10.0 billion, for total annual saving of $10.3 billion.

Finally, treating all heavy users without changing the current budget for supply control would decrease user counts, annual consumption, and societal costs even more. However, restoring the supply-control budget would increase control costs more than it would decrease societal costs, so the total annual saving relative to current policy, $8.1 billion, would be less than that under Alternative C.

Hence, this report concludes that treatment of heavy users is more cost-effective than supply-control programs. One might wonder how this squares with the (dubious) conventional wisdom that, with treatment, "nothing works." There are two explanations. First, evaluations of treatment typically measure the proportion of people who no longer use drugs at some point after completing treatment; they tend to underappreciate the benefits of keeping people off drugs while they are in treatment—roughly one-fifth of the consumption reduction generated by treatment ac-

crues during treatment. Second, about three-fifths of the users who start treatment stay in their program less than three months. Because such incomplete treatments do not substantially reduce consumption, they make treatment look weak by traditional criteria. However, they do not cost much, so they do not dilute the cost-effectiveness of completed treatments.

Does this mean that treatment is a panacea? Unfortunately not, because there is a limit on how much treatment can be done. In our analysis, we explore the consequences of treating every heavy user once each year (Alternatives C and D). In principle, even more treatment is possible because the average duration of a treatment is less than 12 months. However, considering the difficulties of getting people into treatment, more treatment may not be feasible. Treating all heavy users once each year would reduce U.S. consumption of cocaine by half in 2007, and by less than half in earlier years (see Figure S.7).

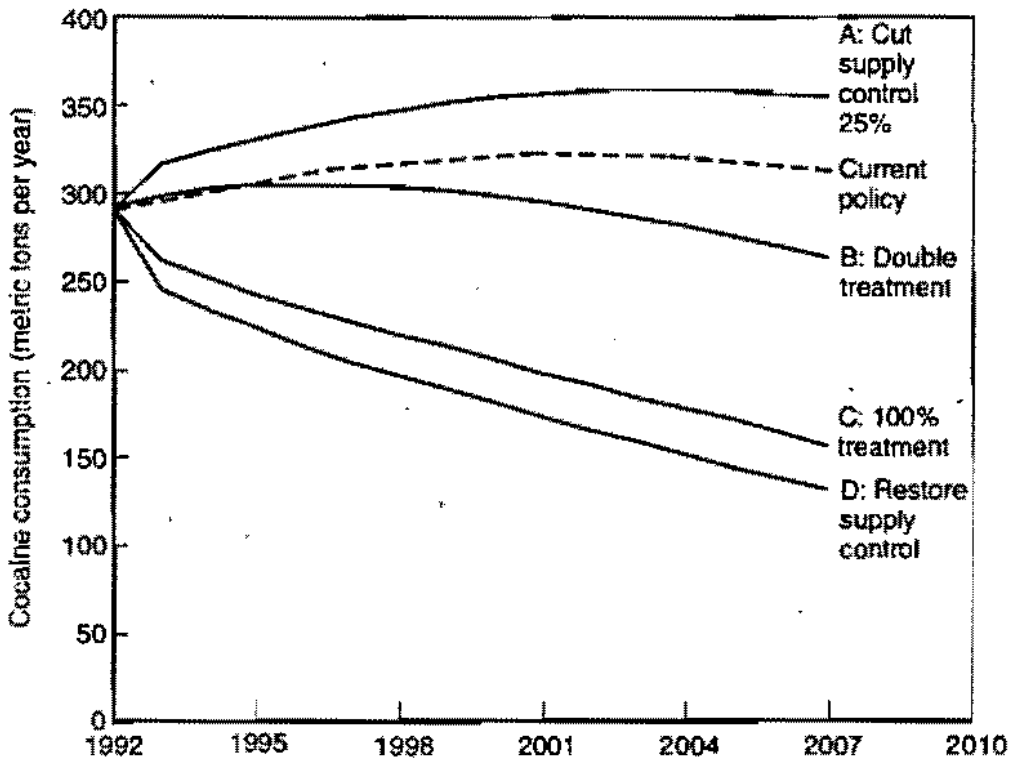

Figure S.7—Dynamics of Change in Cocaine Consumption

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Many people, both at RAND and elsewhere, have contributed to this study—as is to be expected, given that the work was conducted in the context of a wide-ranging research program housed in RAND's Drug Policy Research Center (DPRC). First we acknowledge the support, encouragement, and advice of the current co-directors of the DPRC, Audrey Burnam and Jonathan Caulkins, and of former co-directors Peter Reuter and Barbara Williams. Projects led by Carl Builder and Bonnie Dombey-Moore built the foundations for this modeling work. Parallel work with James Kahan and William Schwabe on RAND's drug policy game helped clarify the relationship between supply-control and demand-control programs, and parallel work with Steven Bankes and James Gillogly on their exploratory modeling project illuminated the global behavior of our cocaine-control model. Concurrent work by Jonathan Caulkins, Michael Childress, Patricia Ebener, Emmett Keeler, Michael Kennedy, Daniel McCaffrey, Peter Reuter, and Kevin Riley, and reviews by Richard Harwood, James Hodges, and Michael Kennedy deepened and improved this analysis.

Helpful suggestions and reactions were also received during work-in-progress briefings given to a variety of institutions, including the Office of National Drug Control Policy (ONDCP), the Drug Enforcement Administration (DEA), the Department of Defense (DoD) Coordinator for Drug Enforcement Policy and Support, and the University of California, Los Angeles (UCLA) Drug Abuse Research Center.

GLOSSARY OF VARIABLES

A	Cost of processing arrests per metric ton of cocaine seized
a	Annual rate at which light users quit using cocaine
ArrestCostRate	Public cost of processing drug dealer arrests
ArrestRate	Arrests of drug dealers per metric ton of cocaine seized
ArrestSanct	Cost to producers of drug dealer arrests
ArrestSanctRate	Cost to drug producers of drug dealer arrests
AssetSanctRate	Assets seized per metric ton of product seized
AssetSanct	Cost to producers of assets seized along with product
B	Budget (public cost of a given type of cocaine control)
b	Annual rate at which light users progress to heavy use
C	Total consumption of cocaine (at a given production stage)
C_h	Cocaine consumption rate of heavy users
C_l	Cocaine consumption rate of light users
CrimeCost	Dollar cost of crime due to cocaine use per dollar expenditure on cocaine
d	Desistance rate (person-years of non-drug-use while in treatment per heavy user treated)
e	Elasticity of demand for cocaine with respect to retail price of cocaine
f	Annual rate at which heavy users regress to light use
ForfeitRate	Proportion of asset seizures salvaged (forfeited to government, as opposed to being destroyed)
G	Gross product of a production stage
g	Annual rate at which heavy users quit using cocaine
H	Heavy users of cocaine
h	Elasticity of processing cost with respect to supply seizures
HeBegUsers	Heavy cocaine users at the beginning of the year
I	Annual incidence of new users

i	Index of production stage
j	Incapacitation rate of light users due to imprisonment of drug dealers
K	Processing cost per metric ton of gross product at a given production stage
k	Ratio of the extra outflow rate caused by treatment to the reference-situation outflow rate from heavy use
L	Light users of cocaine
LiBegUsers	Light users at beginning of the year
m	Ratio of marginal to average productivity of supply control
Maxt	Maximum proportion of heavy users at the start of a year that can be treated during the year
N	Net product of a production stage
n	Incapacitation rate of heavy users due to imprisonment of drug dealers
OutAdd	Additional outflow rate from heavy cocaine use (to either light use or non-use) of heavy users who receive outpatient treatment during the year
OutDesist	Proportion of time during outpatient treatment that clients stop using cocaine
OutDur	Average duration of outpatient treatment
OutTreat	Outpatient treatments of heavy users during the year
P	Price of cocaine at a given production stage
p	Proportion of seizure cost due to relative size of seizure (as opposed to absolute amount seized)
ProdCost	Lost productivity due to cocaine use
PropHeDealer	Proportion of arrested drug dealers who are heavy cocaine users
PropLiDealer	Proportion of arrested drug dealers who are light cocaine users
PrisonCostRate	Public cost of imprisoning drug dealers
PrisonRate	Cell-years of imprisonment of drug dealers per arrest
PrisonSanct	Cost to producers of drug dealer imprisonment
PrisonSanctRate	Cost to producers per cell-year of drug dealer imprisonment
q	Yield factor
R	Cost per residential treatment
r	Annual real discount rate

ResAdd	Additional outflow rate from heavy cocaine use (to either light use or non-use) of heavy users who receive residential treatment during the year
ResDesist	Proportion of time during residential treatment that clients stop using cocaine
ResDur	Average duration of residential treatment
ResTreat	Residential treatment of heavy users during the year
S	Financial sanctions on producers
Seizures	Seizures of cocaine by domestic enforcement
SocialCost	Cost of crime and lost productivity due to cocaine use
T	Total cost of cocaine production at a given production stage
t	Proportion of heavy users treated during the year
TrialT	Proportion of heavy users that can be treated under the available treatment budget
U	Cost per outpatient treatment
V	Value to producers of forfeited assets
v	Low-proportion residential treatment (proportion of all treatments that are residential when essentially no treatments are offered)
W	Seizure cost per metric ton of cocaine seized in reference situation
w	High-proportion residential treatment (proportion of all treatments that are residential when all heavy users are offered treatment during a year)
X	Product seizures
x	Multiplier of additional outflow from heavy use due to treatment (used in sensitivity analyses)
Y	Imprisonment cost of drug dealers per metric ton of cocaine seized (the cost of the cell-years resulting from the arrests that lead to convictions and sentencings)
y	Calendar year
Z	Seizure cost per metric ton of cocaine seized
z	Proportion of all treatments of heavy users that are residential

Chapter One

INTRODUCTION

The cocaine epidemic of the past twenty years is not a unique event in American history. One hundred years ago, between 1885 and 1915, there was a cocaine epidemic in the United States, in which use peaked at the turn of the century (Musto, 1989). It started with cocaine being considered benign, if not therapeutic. Cocaine was as much a part of everyday life at that time as aspirin is today. "Toothache drops" containing cocaine were sold by druggists, and Coca-Cola originally contained a minute amount of cocaine. However, by 1915, anti-cocaine sentiment—just as today, generated in part by fear of crime committed by drug users—had replaced earlier enthusiasm. The nation's first bout with cocaine was rapidly dissipating.

THE SIZE OF THE PROBLEM

The current cocaine epidemic, however, is by no means over. Cocaine use started growing in the late 1960s and picked up momentum during the 1970s. The number of cocaine users peaked in the early 1980s at 9 million and has since declined to a little over 7 million (see Figure 1.1). However, this decline in the number of users does not tell the whole story about cocaine trends.

Total cocaine consumption (shown in Figure 1.2) presents a different picture.[1] Consumption has remained at its mid-1980s peak for almost a decade. As a measure of problem severity, the quantity consumed is at least as relevant as the number of users. Hence, it would be premature to declare victory in the current battle against cocaine.

The downward trend in the total number of cocaine users since the early 1980s is driven by a decline in light users that masks an increase in heavy users. Moreover, the rate of cocaine consumption varies greatly across the two types of users.

[1]The histories of user counts and annual amounts of consumption are given by Everingham and Rydell (1994), who smoothed and interpolated available historical data to produce the curves in Figures 1.1 and 1.2. Prevalence and consumption information in that analysis was obtained from the National Household Survey on Drug Abuse, augmented by estimates from other sources on cocaine use by people who are homeless or incarcerated.

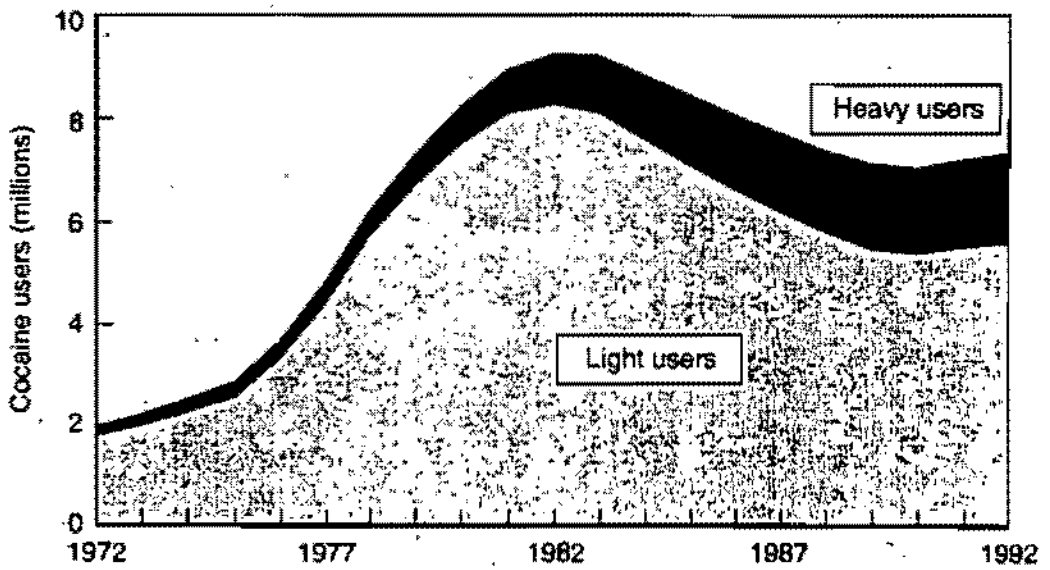

Figure 1.1—Number of Cocaine Users, by Intensity of Use

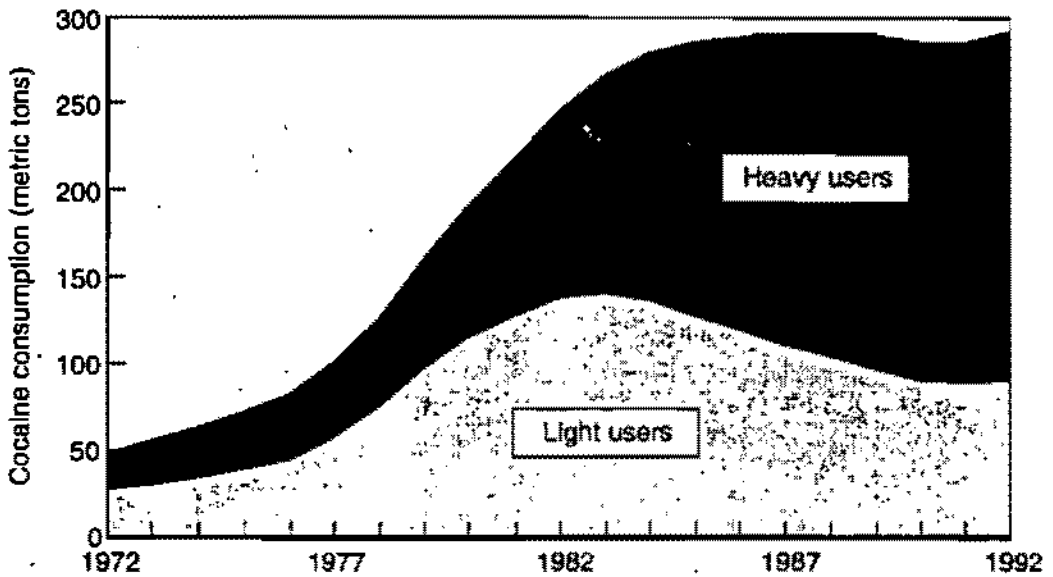

Figure 1.2—Cocaine Consumption, by Type of User

This analysis defines heavy users as people who use cocaine at least weekly, and light users as those who use it at least once a year but less than weekly.[2] Currently, heavy

[2]Some studies (e.g., Hubbard et al., 1989) refer to weekly cocaine users as "regular users"; the National Household Survey on Drug Abuse refers to weekly users as using cocaine "several times a month or more." These definioons are equivalent.

users constitute only about one-fifth of all users (the proportion has varied over time), but they account for roughly two-thirds of total cocaine consumption in this country. In other words, the average heavy user consumes approximately 8 times as much cocaine as the average light user.

On the other hand, the amount of money that users have been spending to obtain their cocaine *has* declined (see Figure 1.3). So if expenditure is used as the measure of problem size, the cocaine problem has declined considerably since the early 1980s.[3]

Since consumption has not declined; falling price must be what is driving expenditure down. That turns out to be the case—with a vengeance. In the past 15 years, the real price of cocaine per pure gram has fallen by more than a factor of 5 (see Figure 1.4).[4] The unadjusted price per gram is roughly constant over time (the bottom line in Figure 1.4), but adjusting for purity (the middle line in Figure 1.4) and then for price inflation (the top line in Figure 1.4) reveals that the real price per pure gram has decreased dramatically.

When competitive pressures cause the price of personal computers to plummet, we cheer the market on gratefully. But when this happens to cocaine, the applause is

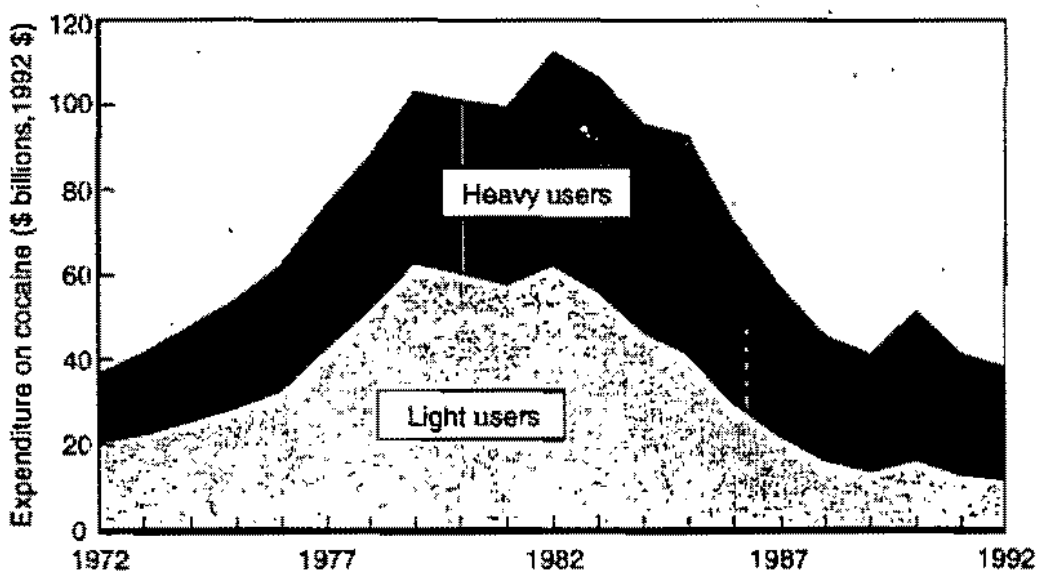

Figure 1.3—Expenditure on Cocaine, by Users

[3]Our estimates of what users in the United States spend on cocaine each year are about double those made by the Office of National Drug Control Policy (ONDCP) using the "consumption approach" (ONDCP, 1991b, p. 5), but they are generally within the range of estimates made using the "supply approach" in that analysis (ONDCP, 1991b, p. 38).

[4]See Appendix A for details on how the observed price of cocaine was adjusted for variations in purity over time and background price inflation to get this real price per pure gram. The primary source is DEA's STRIDE (System to Retrieve Information from Drug Evidence) data. The bump in 1990 is a one-year increase in prices thought by some to be a consequence of a set of unusual enforcement successes in the United States and transshipment countries in that year.

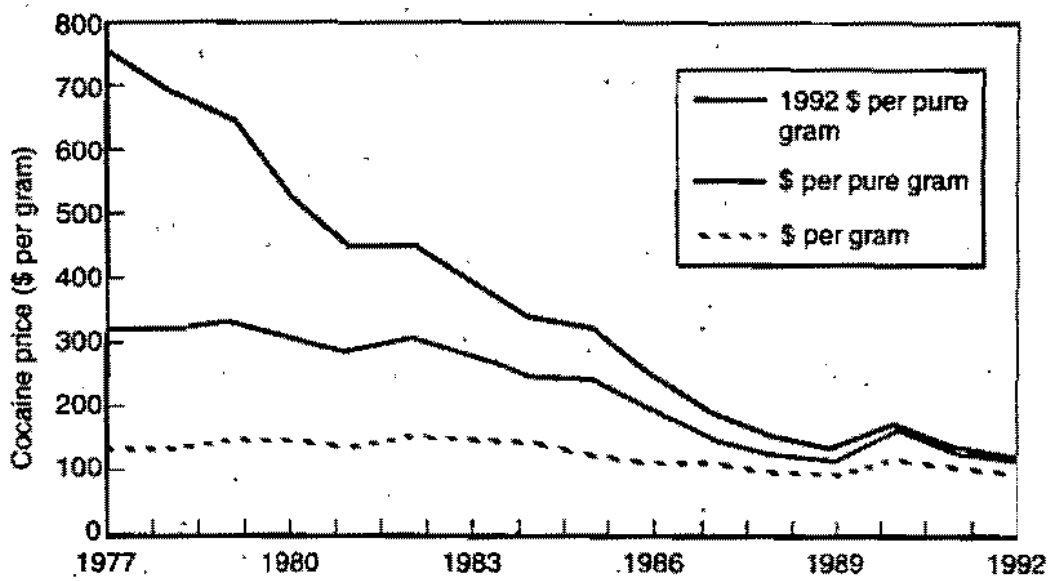

Figure 1.4—Price of Cocaine: 1977–1992

muted. During the past 15 years, the price of cocaine decreased while consumption increased—in spite of escalating public-policy attempts to reverse these trends.

COCAINE-CONTROL PROGRAMS

United States drug-control policy has a long and varied history. Gerstein and Harwood (1990, p. 43) summarize the major enthusiasms as libertarian (at the end of the 1800s), medical treatment (at the beginning of this century), and criminal justice sanctions (from mid-century to the present). At any given time, of course, all three ideas inform public policy; only the proportions in the mix change.

The total expenditure on cocaine control during 1992 was about $13.0 billion.[5] Figure 1.5 shows that domestic enforcement (cocaine seizures, asset seizures, and arrest and incarceration of drug dealers and their agents) accounted for the bulk of cocaine-control expenditures (an estimated $9.5 billion). Interdiction (cocaine seizures and asset seizures by the Coast Guard, the Army, and the Customs Service) has the next largest share (an estimated $1.7 billion). Source-country control (coca leaf eradication and seizures of intermediate and final cocaine products) and user treatments (outpatient and residential treatments) have the smallest shares (estimated to be $0.9 billion each).

[5]These estimated 1992 expenditures are derived from program details in Appendixes A through D. In particular, see Table B.8 in Appendix B and Table D.2 in Appendix D. The estimates include local, state, and federal funds for the war on drugs (prorated to cocaine), and the cost of private as well as public drug treatments (again, prorated to cocaine). One reason for the large size of the domestic enforcement budget is that it includes the jail and prison costs for incarcerating convicted drug dealers and their agents; the jail and prison costs constitute one-fourth of the domestic enforcement total (see Table B.8 in Appendix B).

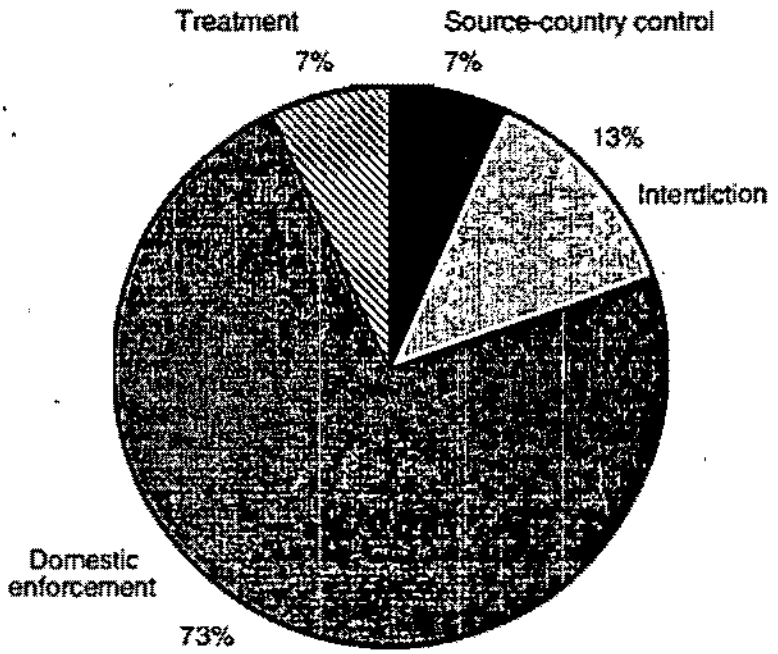

Figure 1.5—Distribution of Annual Expenditures on Cocaine Control: 1992

Cocaine control strategies can usefully be classified into two categories, supply control and demand control (see Figure 1.6). As defined here, supply control includes source-country control in South and Central America, interdiction at the U.S. border by the Coast Guard, the Army, the Customs Service, and the Immigration and Naturalization Service (INS), and domestic enforcement of drug laws by a variety of federal agencies, the most prominent of which is the Drug Enforcement Administration (DEA), as well as by state and local police forces. Demand control includes outpatient and residential drug treatment programs, which are analyzed in this report, and user sanctions (arrest and incarceration of drug users) and prevention programs (both school-based and community-based), which are not analyzed in this report.

Note that there are other ways of classifying drug control programs. For example, the 1988 Anti-Drug Abuse Act defines supply reduction programs more broadly to include such things as user sanctions.

Analyzing user sanctions and prevention programs is beyond the scope of the present analysis. Far less evidence is available on the costs and accomplishments of these programs than now exists for supply-control and treatment programs.[6] Also,

[6]See MacCoun (1993) for a discussion of the complexities of analyzing the effects of user sanctions. Botvin (1990) argues that community-based prevention programs have not been shown to affect drug use. Reviews of past studies (for example, Falco, 1992) and reports on the recently completed Project ALERT (Ellickson and Bell, 1990a, 1990b; and Ellickson, Bell, and Harrison, 1993) indicate that school-based prevention programs do decrease drug use. However, the emphasis in prevention research has so far (appropriately) been on establishing statistically significant effects on drug prevalence, leaving effects on amounts of drugs consumed and program costs yet to be investigated.

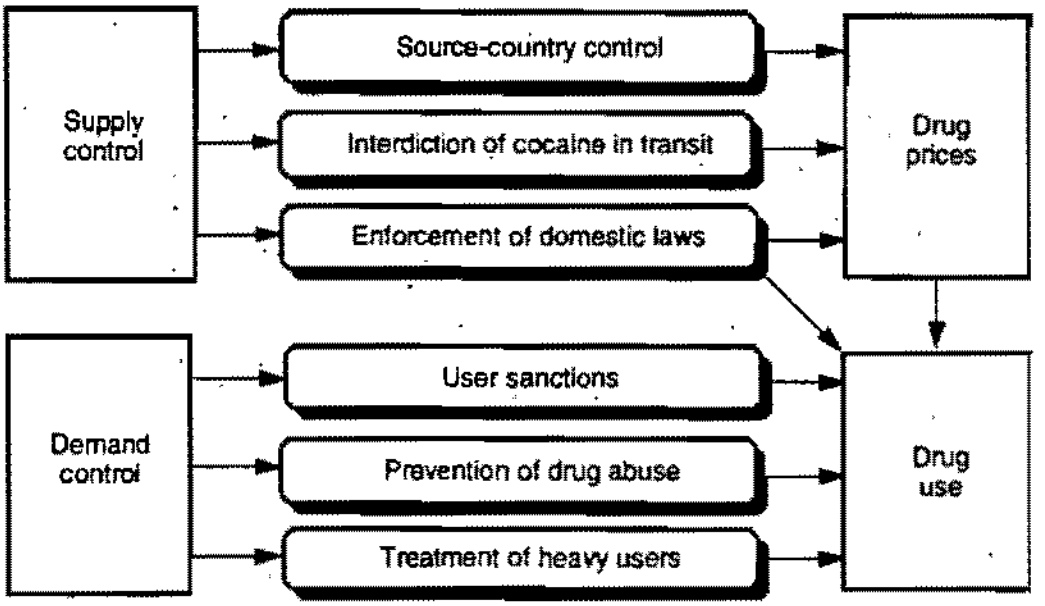

Figure 1.6—Alternative Control Programs

prevention programs operate on a different time scale than treatment or supply-control programs. For example, most drug prevention programs are administered to preteens, while cocaine use does not normally start until the late teens and early twenties.[7]

A primary activity of supply-control programs is seizing cocaine. This, however, does not directly decrease the supply of cocaine reaching the retail market. Free entry into the cocaine business, at all levels, allows supply to expand to cover the losses due to seizures.[8] To a first-order approximation, suppliers simply produce for the market what they would have produced anyway plus enough extra to cover anticipated government seizures.

This simple story overstates matters slightly, because supply controls in general, including product seizures, raise the price suppliers charge the consumer, and that price increase cuts off some demand. There is, however, an exception to the general rule that supply controls operate through price. This exception is the "incapacitation effect" (indicated by the arrow in Figure 1.6 that goes directly from domestic enforcement to consumption). Many drug dealers are also drug users, and they cannot

[7]See Kandel and Logan (1984), Yamaguchi and Kandel (1984a), and Kandel, Murphy, and Karus (1985) for the typical ages of initiation for various drugs. Prevention programs attempt to convince preteens to abstain from marijuana, cigarettes, and alcohol. Therefore, to argue that drug-abuse prevention programs cut cocaine incidence, one must assume that marijuana, cigarette, and alcohol use are "gateways" to "hard drugs" such as cocaine and heroin. However, the gateway linkage is difficult to pin down (Yamaguchi and Kandel, 1984b; DuPont, 1989; Ellickson, Hays, and Bell, 1992).

[8]Competitors may violently object to new entrants to the trade, and government will try to put them in prison (both of these factors increase the cost of doing business), but there are no prohibitive capital-requirement, rare-skill, or institutional barriers to entering the cocaine supply business.

sustain their normal consumption rate while in prison. Consequently, even through the primary effect of locking up drug dealers is to increase the costs of supplying cocaine (which indirectly affects the quantity consumed via price increases), there is also an incapacitation effect (which directly affects demand). Both are included in the present analysis.

Treatment programs, on the other hand, affect demand directly. Treatment programs decrease cocaine consumption in two ways: First, most people reduce consumption while in treatment and, second, some people do not return to their original levels of consumption after they leave treatment. This report considers both forms of treatment-induced reductions, for both outpatient and residential treatment programs.

THE MODEL

To examine the effects of the three supply-control programs plus treatment, we constructed a model of the supply and demand for cocaine, and of how control programs affect supply and demand. The model is documented in the appendixes to this report.

The measurable accomplishments of supply-control programs include quantities of cocaine seized, value of assets seized, and numbers of drug dealers and their agents arrested and the amounts of time they are incarcerated. The measurable accomplishments of drug treatment programs include the number of people who stop using drugs while in treatment and the number who stay off drugs after leaving treatment. These outcome measures cannot be directly compared, however. They must first be translated by the model into a common measure of cost-effectiveness.

For most of the following analysis, the common measure used is the cost of a given reduction in U.S. consumption of cocaine.[9] More specifically, it is the additional control cost in the first projection year which results in consumption decreases over 15 projection years that have a net present value equal to 1 percent of total consumption in the first projection year.

A 4 percent real discount rate is used to compute the present value of the 15 years of consumption reductions. Discounting costs is a familiar technique: Everyone understands that money can be invested to earn interest.[10] However, there is not always a similar automatic recognition that benefits must be discounted as well as costs when constructing a cost-effectiveness ratio. A simple example can make the necessity of discounting benefits clear. Suppose there are two plans:

---

[9]However, in Chapter Five we explore the consequences of using two alternative evaluation criteria: (1) the number of cocaine users, and (2) the societal costs of crime and lost productivity caused by cocaine use.

[10]In fact, that is how the appropriate discount rate is defined: "The discount rate is conventionally applied to constant-value (i.e., inflation adjusted) dollars. With moderate inflation, the discount rate is approximately the interest rate less the expected rate of inflation" (Keeler and Cretin, 1982, p. 4).

- Plan A costs $30 million this year and reduces cocaine consumption by 3 metric tons this year.
- Plan B costs the same $30 million this year but does not deliver the 3 metric tons of consumption reduction until next year.

If the benefit of cocaine consumption is not discounted, the two plans are the same. However, by taking $28.8 million this year and investing it so that it grows to $30 million next year, we would get enough money to implement Plan A next year. Plan A has been transformed into one that costs only $28.8 million and delivers the same benefit as Plan B. Clearly, Plan A is more cost-effective than Plan B.

This example shows that benefits must be discounted to correctly evaluate the cost-effectiveness of alternative plans. It also shows that the discount rate used for benefits must be the same as the one used for costs. Keeler and Cretin (1982) present an extensive mathematical discussion of the point made by this example. An earlier version of the example can be found in Rydell (1987, pp. 3–6).

Over the years, a variety of models have been used to inform drug policy analysis (Schlenger, 1973; Levin, Roberts, and Hirsch, 1975; Gardiner and Schreckengost, 1987; Cave and Reuter, 1988; Crawford and Reuter, 1988; Caulkins, 1990; Homer, 1990, 1993a, 1993b; Caulkins, Crawford, and Reuter, 1993; Kennedy, Reuter, and Riley, 1994; and Riley, 1993). What distinguishes the present study is its scope: the comparison of both supply- and demand-control programs on both cost and effectiveness dimensions. In part because of this broad scope, the modeling is done in a very transparent manner, to minimize the chance of missing the forest for the trees.

As Bankes (1993) and Hodges (1991) point out, one does not necessarily need complete information on a system to model it usefully. Rather, a model may illuminate system behavior and assist policy choices, with only partial knowledge. In this analysis, neither uncertainties about parameter estimates (see Chapter Four and Appendix F) nor the existence of multiple drug-control goals (see Chapter Five) alters the conclusion that treatment is more cost-effective at the margin than enforcement.

OVERVIEW OF THE REPORT

The plan of this report is as follows: Chapters Two through Five explore the results of changing one cocaine-control program at a time. Chapter Six synthesizes these results to construct and compare alternatives to current policy.

Chapter Two, supported by Appendixes A and B, analyzes supply-control programs. Chapter Three, supported by Appendixes C and D, analyzes treatment programs. Both sets of analyses draw on the model, which is described in Appendix E. Chapter Four and Appendix F examine the robustness of the conclusions with respect to variations in parameter estimates whose values are known only approximately. Chapter Five considers alternatives to the consumption criterion for evaluating program effectiveness. Finally, the composite policy alternatives compared in Chapter Six range from costing $3 billion per year less than the $13 billion per year currently spent on cocaine control to costing $2.6 billion per year more.

Cocaine is produced in South America, primarily in Peru, Bolivia, and Colombia. The raw agricultural product, coca leaf, goes through a series of production stages before it becomes cocaine. The cocaine produced is transported to the destination country and marketed there (see Figure 2.1). At every stage in the production process, there are losses and seizures. At some stages, there is non-U.S. consumption. In this analysis we are interested in the amount that reaches the United States; but to understand that, we need to analyze the entire production pipeline.

Except in the tables in Appendix A, this study aggregates the first four steps in the diagrammed production process into a single step: source-country production. (See Kennedy, Reuter, and Riley (1994) and Riley (1993) for analyses of what goes on inside source countries.)

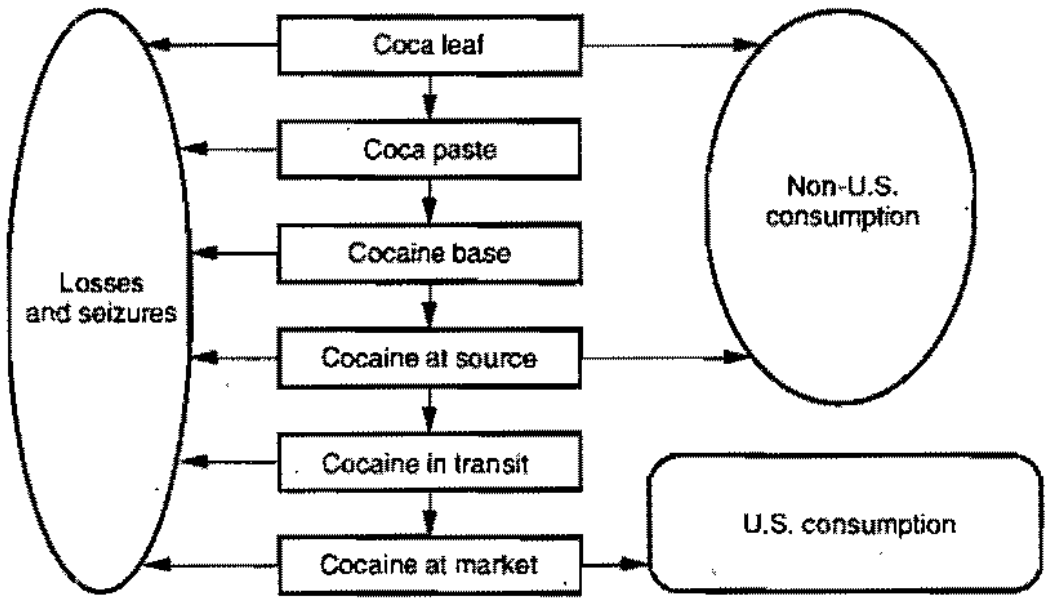

Figure 2.1—Cocaine Supply Flows

HOW SUPPLY-CONTROL PROGRAMS WORK

As mentioned in Chapter One, at each production stage the gross product has to cover the losses to control-program seizures and still deliver the net product that is the input to the next stage (see Figure 2.2). Even though producers make up the seizure losses by expanding gross production, they are still hurt by the seizures. They get no revenue from the seized product, so they must raise the price of the surviving net product to cover their production costs.

Supply-control programs do more than indirectly raise the cost of doing business by seizing product. They also impose "financial sanctions" on producers that directly raise the cost of doing business. In this analysis, the label "financial sanctions" is broadly interpreted. It includes the loss to producers from asset seizures (financial and transportation) and the increased production costs required to compensate workers for the risks of arrest and imprisonment.

Moreover—and this effect does not usually get tabulated in statements of supply-control program accomplishments—supply-control programs also cause processing costs to increase. By "processing costs" we mean all contributions to total cost other than the cost of the input from the previous production stage, and the financial sanctions (see Figure 2.3, which is based on analyses in Appendix A). For example, processing costs, as we define them, include distribution costs. Supply-control programs cause processing costs to increase because producers adapt to government actions against them. In particular, producers incur costs to disguise their production and distribution, to guard it against law enforcement, to gain intelligence about law enforcement plans, and to otherwise prevent law enforcement agents from discovering production and from disrupting production when it is discovered. If we did

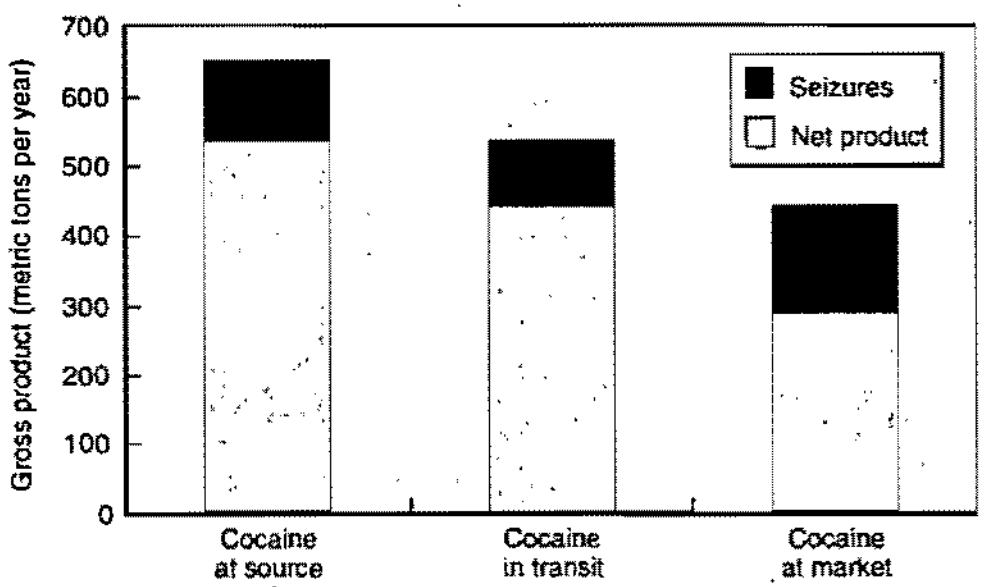

Figure 2.2—Cocaine Production: 1992

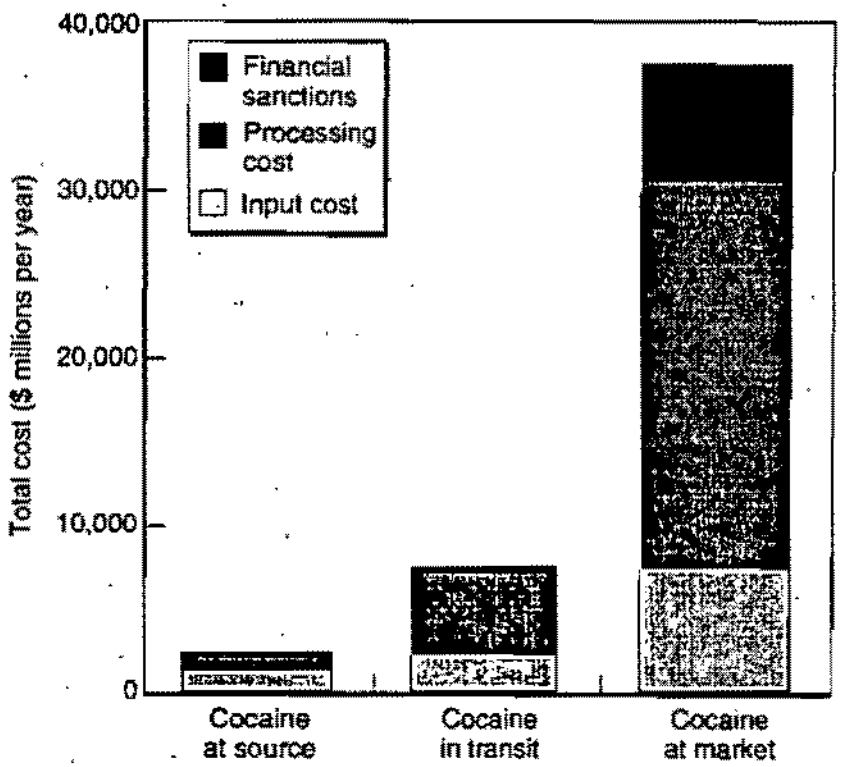

Figure 2.3—Cost of Cocaine Production: 1992

not estimate this increase in processing costs, we would underestimate the impact of supply-control programs on producer costs and hence on price.

Thus, supply-control programs harm cocaine producers in three ways: by seizing product, by imposing financial sanctions, and by causing processing costs to increase. The aggregate effect is to cause the price of cocaine to skyrocket (see Figure 2.4). What starts out costing just over $4,000 per kilogram at the airstrip in South America ends up costing well over $100,000 on the street in North America.[1] Moore (1990, p. 115) has estimated that the retail price of cocaine would be only one-eighth as large if cocaine were legal (that is, absent the effect of supply controls). His specific estimates (for 1988) are $15 to $20 per pure gram if cocaine were legal, as opposed to $143 per pure gram under its illegal status.

EFFECTS ON COCAINE CONSUMPTION

What do each of these supply-control effects contribute to the decreases in cocaine consumption achieved via additional expenditure on the supply-control programs?

[1]Note that the price of the net product at a given production stage equals the total cost of production at that stage divided by the net product at that stage. See Tables A.1 through A.6 in Appendix A for details of this relationship.

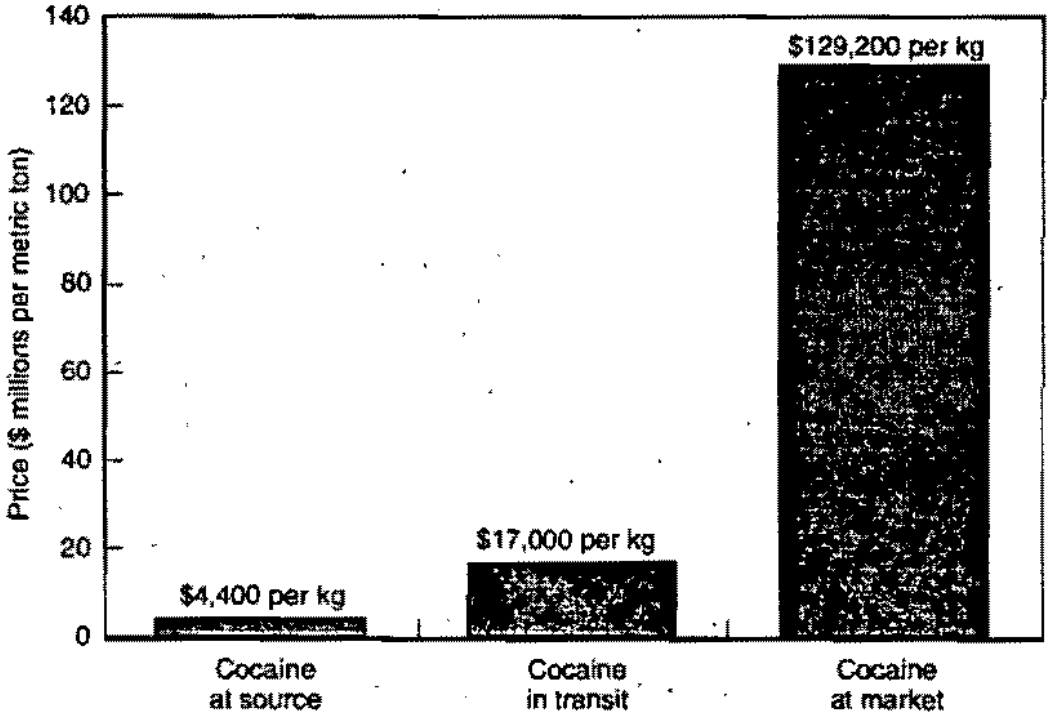

Figure 2.4—Price of Net Product, by Production Stage: 1992

Figure 2.5 shows that product seizures by themselves account for only about two-fifths of supply-control programs' effect on cocaine consumption. Financial sanctions (asset seizures plus compensation to drug dealers and their agents for the risk of arrest and incarceration) contribute one-sixth of the effect. Processing cost increases (as cocaine producers seek to avoid product seizures and financial sanctions) account for one-third of the effect. Finally, an estimated 7 percent of the effect is accounted for by drug dealers in jail or prison who are prevented from continuing their customary levels of cocaine use. This incapacitation effect on consumption is in addition to the financial impact of wage premiums paid for the risk of incapacitation.[2]

The cost-effectiveness of the three supply-control programs is determined by running the cocaine-control model separately for each program, each time finding the

[2]The proportions in Figure 2.5 represent all three control programs combined. They were estimated by using the cocaine-control model. The expenditures for source-country control, interdiction, and domestic enforcement (state and local expenditures as well as federal expenditures) were first all increased by the same percentage to find the overall effect of supply control on consumption at the margin. Then the model was rerun with the elasticity of processing cost with respect to product seizures set to zero to find the processing cost effect by noting how much less effect supply controls then have on consumption. Next, the model was run with the proportions of arrested drug dealers who use cocaine set to zero to find the incapacitation effect. The residual was then attributed to product seizures and financial sanctions. Finally, the relative contribution of product seizures and financial sanctions was determined by the ratio of the sum of product seizures times price at each production stage to the sum of financial sanctions at each production stage (see Tables A.6 through A.8 in Appendix A).

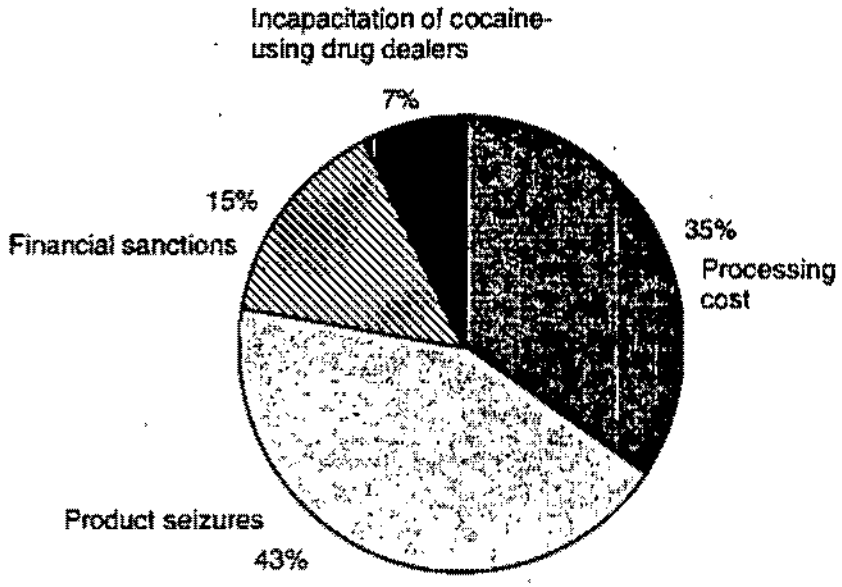

Figure 2.5—Proportion of Consumption Reduction Caused by Separate Supply-Control Effects

additional program expenditure[3] in the first projection year required to achieve consumption reductions over 15 years whose present value is 1 percent of total consumption in the first year. This cost turns out to decline with each stage in the cocaine production process. Accomplishing the specified reduction in cocaine consumption costs $783 million with source-country control, $366 million with interdiction, and $246 million with domestic enforcement (see Table 2.1).

In each case, the money spent on supply control causes increases in the cost to producers of supplying the cocaine. That increased cost of supply gets passed along to the consumer as price increases, which in turn causes current consumption per user to decline and eventually causes the number of users to decline as inflows to cocaine use decrease and outflows increase. For example, a $246 million additional annual expenditure on domestic enforcement causes annual cocaine supply costs to increase by an estimated $750 million, or 2 percent of the estimated $37.6 billion spent annually by consumers on cocaine. Assuming, as we do in this analysis,[4] that the total percentage decrease in consumption caused by a price increase is half the percentage price increase, the additional control expenditure achieves the goal of reducing consumption by 1 percent.

[3]"Program expenditure," as used in this report, means all program funding: federal, state, and local; public and private.

[4]Appendix C discusses this price elasticity assumption. Chapter Four and Appendix F assess the sensitivity of this report's results to the assumption.

Table 2.1

Effect of Supply-Control Programs on Cocaine Consumption

Control Program	Cost of 1% Decrease in Cocaine Consumption ($ millions/yr)	Program Cost Relative to Domestic Enforcement
Source-country control	783	3.2
Interdiction	366	1.5
Domestic enforcement	246	1.0

NOTE: These costs are the additional control costs in the first projection year which result in consumption decreases over 15 projection years that have a net present value equal to 1 percent of the first year's consumption.

One is tempted to observe that intervening later in the production process will be more cost-effective, since seized product is more costly to replace at those later stages.[5] However, this argument, although correct as far as it goes, is only part of the story. For example, the cost-effectiveness of a supply-control program is determined not only by the cost to the producers of replacing the product seizures, but also

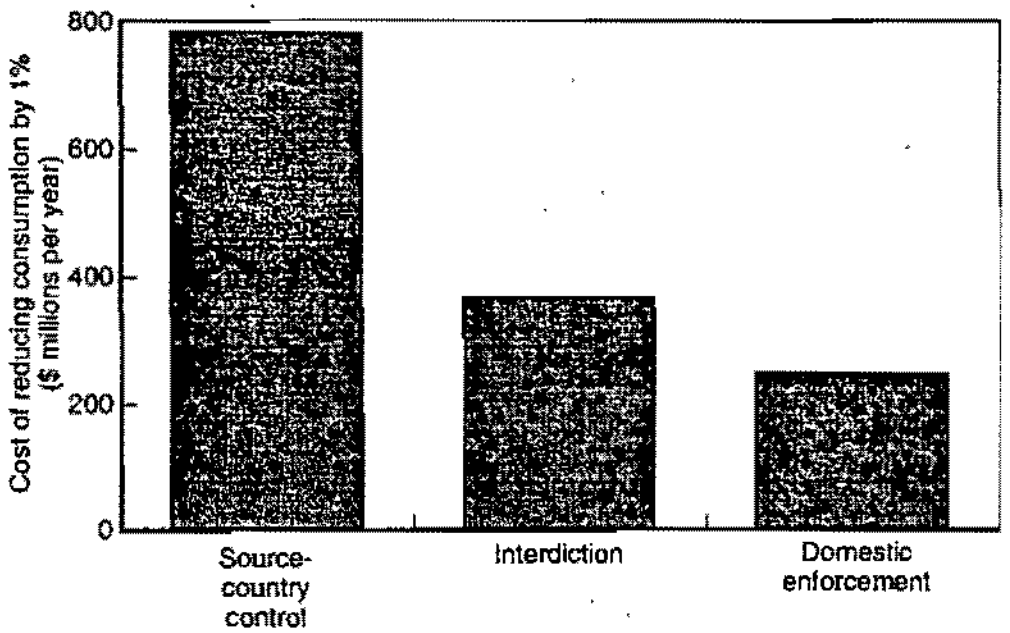

Figure 2.6—Cost of Reducing Consumption by 1 Percent with Alternative Supply-Control Programs

[5]While incomplete, this argument is correct and must be included in a cost-benefit analysis (as it is in our cocaine-control model). This point was overlooked in a previous study comparing the cost-effectiveness of interdiction and domestic enforcement (Godshaw et al., 1987). That study incorrectly concluded that interdiction was more cost-effective than domestic enforcement, because its criterion was metric tons seized per program dollar (which does not recognize that a metric ton seized at the retail market does more harm to producers than a metric ton seized at the border). In addition, that study looked only at product seizures; it did not analyze asset seizures or arrest and imprisonment of drug dealers.

by the cost to the public of accomplishing those seizures. Nevertheless, even when our analysis takes this and other factors into account, the qualitative result is the same as if we had considered only the replacement cost of product seizures: The later in the production process one intervenes, the more cost-effective the intervention (see Figure 2.6, which plots the results given in Table 2.1).

CONSUMPTION OF COCAINE

The approximately 7.3 million cocaine users in the United States at the end of 1992 consisted of an estimated 5.6 million light users and 1.7 million heavy users. These estimates include cocaine users who were homeless and those who were in jail or prison, as well as those in households (see Fig. 3.1).[1] Recall that, by definition, "heavy use" means at least weekly, and "light use" means at least once a year, but less than weekly.

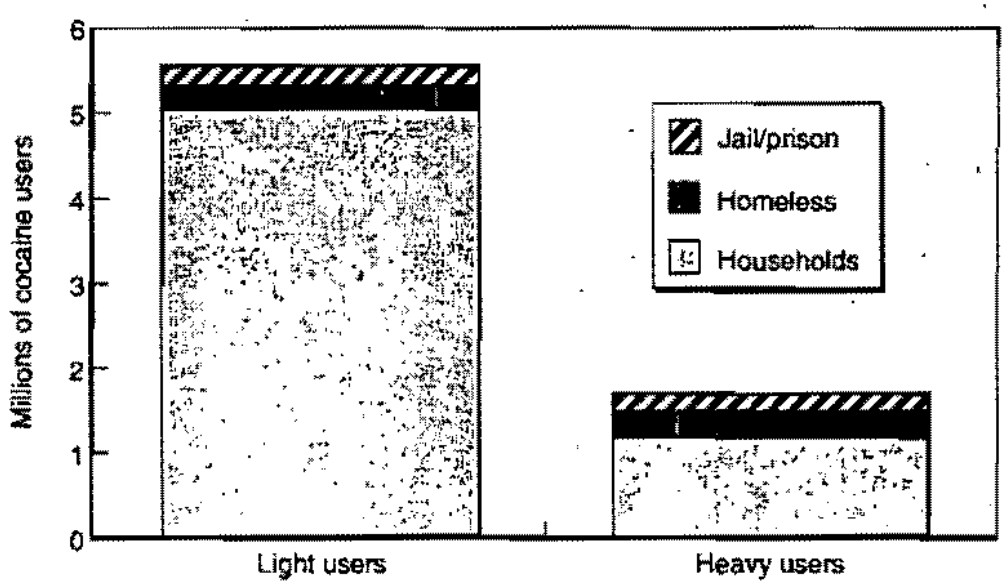

Figure 3.1—Light and Heavy Cocaine Users, by Location: 1992

[1] For more detail on these estimates of numbers of cocaine users, see Table C.1 in Appendix C. For the derivation of the estimates, see Everingham and Rydell (1994). Note that the estimate of 1.7 million weekly cocaine users is within the 1.5 to 2.5 million range estimated by Rhodes (1993, p. 312). This analysis assumes that no cocaine consumption occurs while cocaine users are actually in jail or prison. However, at the same time, no presumption is made that jail or prison is an effective treatment program—on the contrary, this analysis assumes that people in jail or prison come out using cocaine in the same proportions and in the same amounts as they would have if they had never been incarcerated. People in jail or prison were classified as heavy or light users on the basis of their answers to survey questions on their cocaine consumption habits in the year preceding their incarceration.

As mentioned in Chapter One, it is important to focus on differences between light and heavy users. For example, in 1990, heavy cocaine users comprised approximately one-fifth of all users, yet they accounted for about two-thirds of all consumption (see Figure 3.2). In other words, the rate of consumption for heavy users is about 8 times that for light users. Since treatment programs tend to focus on heavy users (this analysis assumes that only heavy users are treated), treatment-program effectiveness is estimated to be much higher than it would be if average consumption rates were used in the analysis.

Gerstein and Harwood (1990, pp. 59–62) have summarized the literature on individual drug histories in a multistage conceptual model. The stages are abstinence, initial use, abuse, dependence, and recovery. People not only flow along this sequence, they can also flow back to earlier stages. Unfortunately, available data do not permit estimation of all the states and flows in Gerstein and Harwood's model. Our research adopts a simplified version of their conceptual model that can be estimated with available data (see Figure 3.3 and Appendix C).

This demand model is sufficiently detailed to be able to replicate three observed historical patterns (Everingham and Rydell, 1994):

- The increase of cocaine prevalence during the 1970s and early 1980s, followed by a decrease during the late 1980s.
- The decline in cocaine use as a cohort ages (only 30 percent of users still use cocaine a decade after starting).
- An increase in the percentage of users who were heavy users during the late 1980s.

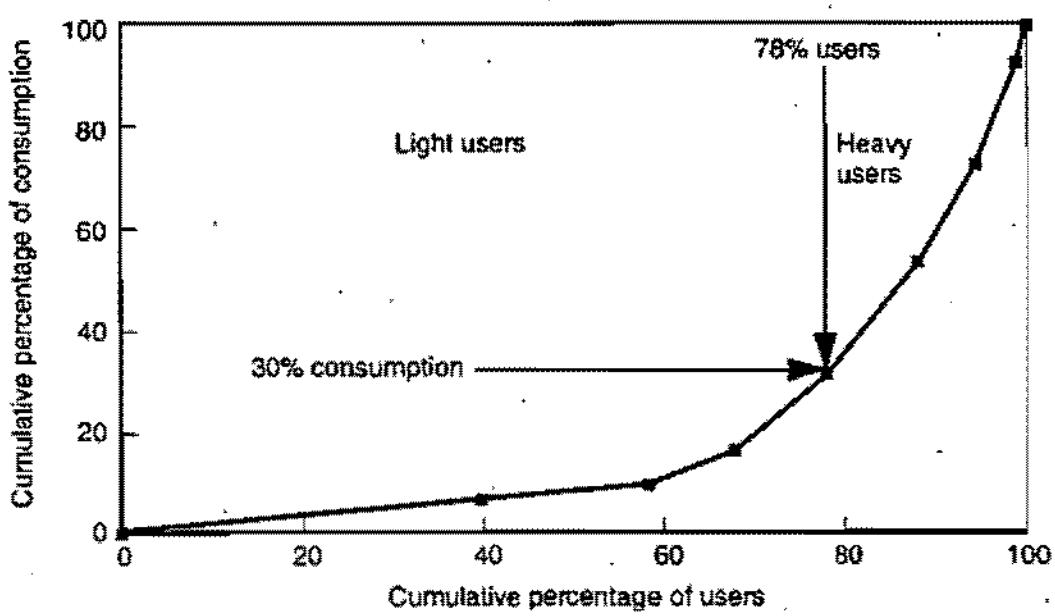

Figure 3.2—Cocaine Users vs. Total Consumption: 1990

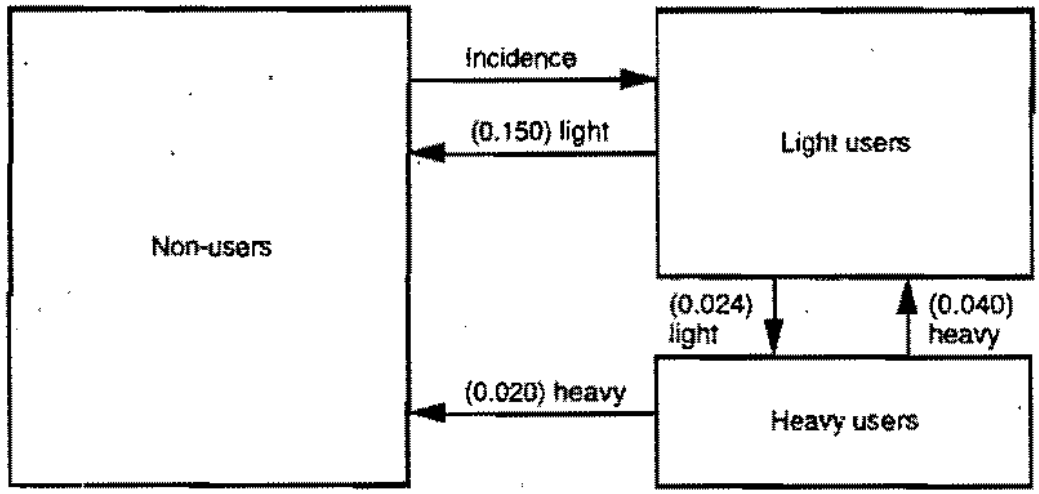

Figure 3.3—Annual Dynamics of Cocaine Use

The parameter estimates that enable the model to replicate these historical patterns are given in Figure 3.3. On the basis of the historical evidence, we estimate that each year 15 percent of the light users stop using cocaine, while 2.4 percent of the light users shift to heavy use. Then, also each year, 4 percent of the heavy users return to light use, while 2 percent stop using cocaine entirely, for a total outflow from heavy use of 6 percent per year. The heavy users who flow back to light use are at risk of relapsing to heavy use. However, in our model, light users who are former heavy users have the same annual probability of becoming heavy users again as light users who have never yet been heavy users.

Incidence is not specified as a function of anything else. Rather, in our model, incidence is scripted. When we are replicating history, estimates of historical incidence are model inputs. Projections of the future are conditional upon an assumed incidence scenario, namely that (at the reference-year price of cocaine) the number of new cocaine users each year will decline linearly from an estimated 1 million per year in 1992 to half that level in 2007 (see Appendix C). This analysis is not designed to predict the future course of the cocaine epidemic. Rather, it has the more limited objective of assessing how alternative public control policies would affect a given presumed course of that epidemic.

CHARACTERISTICS OF TREATMENT PROGRAMS

Outpatient treatments and residential treatments differ considerably. Outpatient treatments are shorter[2] and relatively inexpensive, and they account for the bulk of

[2]Methadone treatments can continue indefinitely, but they are classified separately in the source of this information (Hubbard et al., 1989), which distinguishes among outpatient methadone treatments, outpatient drug-free treatments, and residential treatments. Only the latter two are relevant for cocaine users, so for simplicity, our analysis refers to outpatient drug-free treatments as "outpatient treatments."

the caseload; residential treatments are longer, relatively expensive, and less commonly used (see Table 3.1).

On average, treatment programs are about 80 percent effective at keeping users off cocaine while they are actually in the program. They are much less effective at keeping users off cocaine after completing treatment (and many people who begin treatment leave before the treatment is complete).

Follow-up information obtained by the Treatment Outcome Prospective Study (TOPS)[3] indicates that, on average, an estimated 13.2 percent of the people who receive treatment flow out of heavy use during the year in which they receive treatment. This estimate is a weighted average of a 12.2 percent rate for outpatient treatment and a 16.7 percent rate for residential treatment (see Table 3.1, which is based on details presented in Appendix D). This rate of outflow from heavy use due to treatment is in addition to that of people who would have left heavy use without treatment. In other words, the treatment effect is the additional outflow of persons who receive treatment compared with a control group of those who do not receive treatment.[4]

Our studies show that about 6 percent of heavy users leave heavy use each year (Figure 3.3). About two-thirds of that outflow is apparently due to existing treatment programs, because at a 13 percent additional outflow rate, the 32 percent of heavy users currently treated each year (Table 3.1) generate a 4 percent annual outflow from heavy use. In other words, only one-third of the total annual outflow from heavy use is estimated to be due to unassisted desistance from heavy use.

Table 3.1

Treatment Program Characteristics

Characteristic	Type of Treatment		
	Outpatient	Residential	All
Program Levels (Accessions) in 1992			
Percent of all treatments	77.5	22.5	100.0
Percent of all heavy users	24.5	7.1	31.6
Program Cost and Duration			
Cost per treatment (1992 $)	762	5107	1740
Treatment duration (years)	0.280	0.410	0.309
Cost per person-year (1992 $)	2722	12467	5626
Program Effectiveness			
Off drugs during treatment (%)	73	99	79
Additional outflow rate (%)	12.2	16.7	13.2

SOURCES: Butynski et al. (1990) and Hubbard et al. (1989). See Appendix D in this report for the details obtained from those sources.

[3]Hubbard et al. (1989) discuss the TOPS study, in which the statistics on treatment effectiveness are reported (p. 180). For the derivation of the 13.2 percent estimate from those statistics, see Tables D.3 and D.4 in Appendix D of the present report.

[4]As discussed in Appendix D, the control group consists of people who enter treatment but drop out before completing treatment (operationally, those who stay in treatment less than three months).

Results from earlier studies of drug-treatment effectiveness generally support the TOPS findings (Anglin and Hser, 1990). In particular, using "intake only" as the control,[5] the Drug Abuse Reporting Program (DARP) results for heroin use are very similar. Additional outflow from daily opiate use is 13 percent for outpatient drug-free treatments and 15 percent for residential treatments (Anglin and Hser, 1990, p. 470).

Following the pattern in the estimated historical flows out of heavy use (see Figure 3.3), we judge that one-third of the treatment-induced outflows from heavy use go to non-use; the remaining two-thirds go to light use and face the risk of returning to heavy use in the future. Our cocaine-control model keeps track of this feedback effect and incorporates it into our overall estimates of treatment-program effectiveness.

The average treatment costs $1,740. (This is cost per accession, not cost per person-year.) This estimate is a weighted average of outpatient and residential treatment costs. The cost per treatment seems surprisingly low, as does the 13 percent additional outflow rate, until one realizes that most treatments end prematurely. Following Hubbard et al. (1989), we use the 3-month point as a minimal length of time for a treatment program to have any chance of accomplishing something. About two-thirds of treatments fail to reach this threshold (see Figure 3.4). These truncated attempts at treatment depress both the average cost and the average effectiveness of treatment programs.

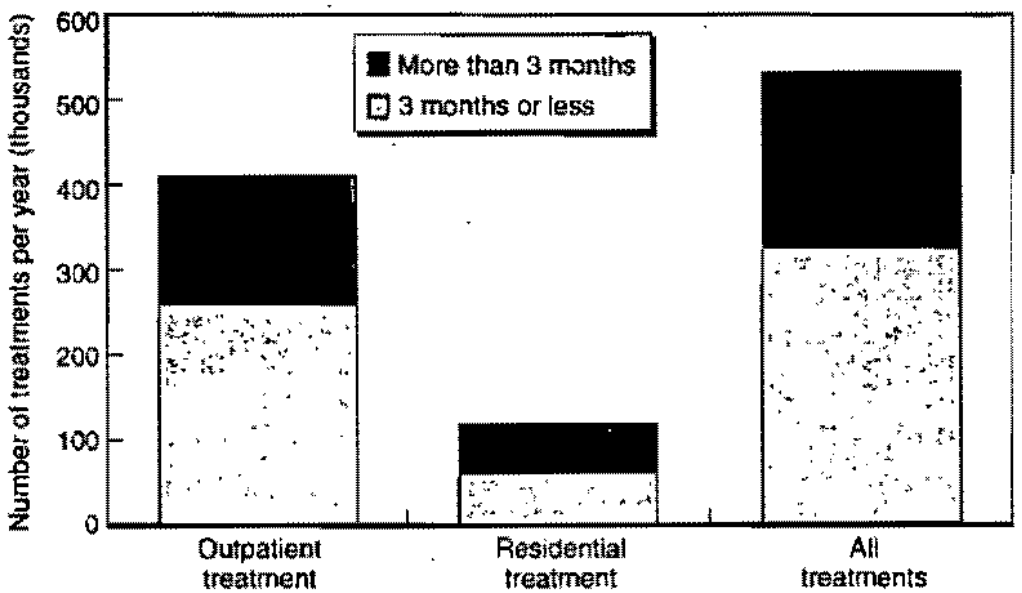

Figure 3.4—Number of Treatments per Year, by Treatment Duration

[5]That is, the control group consists of people who signed up for treatment but did not actually receive an appreciable amount of treatment.

When one focuses on the treatments that last longer than three months, the cost per treatment (again, per accession, not per person-year) is considerably higher than the average cost (see Figure 3.5), and the additional outflow from heavy use is also considerably higher than the average (see Figure 3.6).

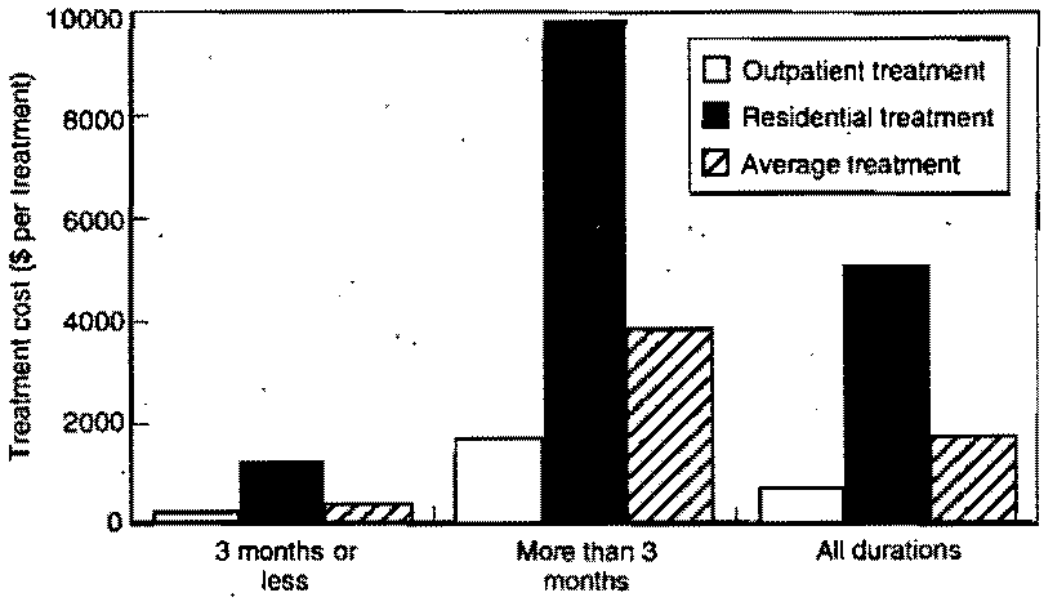

Figure 3.5—Cost per Treatment Accession (1992 dollars)

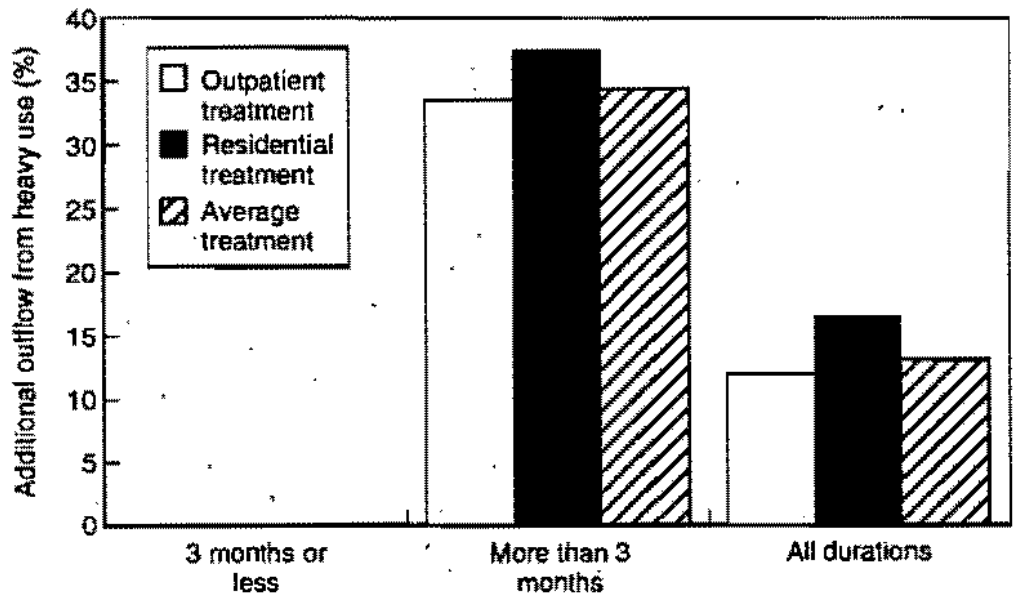

Figure 3.6—Additional Outflow from Heavy Use Due to Treatment (percentage of those receiving treatment)

Note that the estimated additional outflow rate for treatments lasting less than three months is zero in Figure 3.6, because this analysis uses the short-treatment group as a "control group" (see the discussion in Appendix D). To the extent that the short treatments do have some positive effect on after-treatment behavior, this analysis underestimates the effectiveness of treatment programs.

EFFECTS ON COCAINE CONSUMPTION

Figure 3.7 shows how much of the consumption reduction caused by treatment is due to people consuming less cocaine while in a treatment program, and how much is due to them consuming less cocaine after treatment.[6] The in-treatment effect occurs immediately, while the after-treatment effect occurs over time because it is the aggregation of annual differences between what would have happened without treatment and what happens with treatment.

Even though the debate on the effectiveness of treatment focuses on treatment's ability to get people to stay off drugs after they leave a treatment program, one-fifth of treatment programs' overall effectiveness is due to the suppression of cocaine use while people are in treatment. Ignoring this effect in an analysis of treatment-program effectiveness would underestimate program benefits.

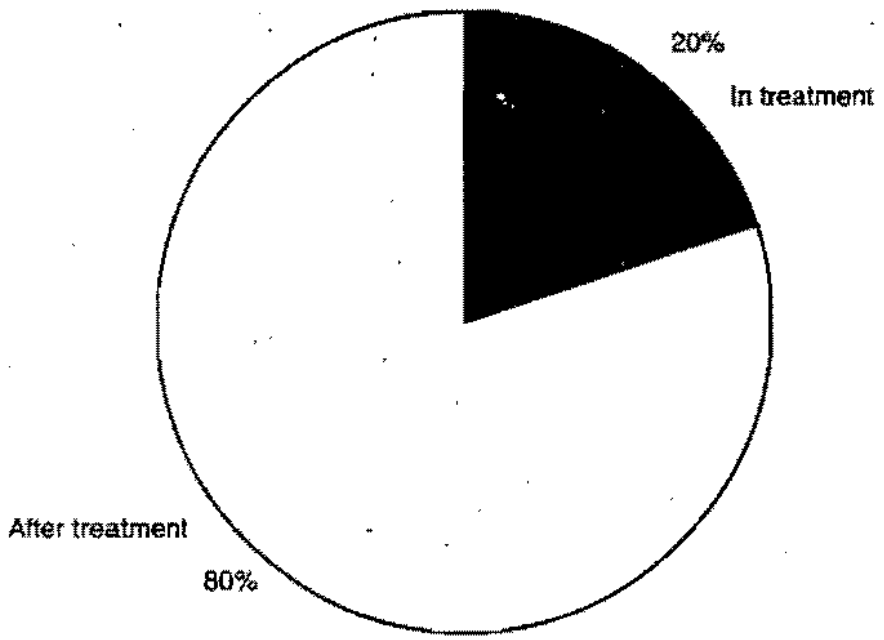

Figure 3.7—Proportion of Consumption Reduction Caused by Separate Treatment Effects

[6]The in-treatment effect was found by running the cocaine-control model with the desistance rate, d, set equal to zero, in which case $250 million additional treatment dollars decreased consumption by only 9.4 metric tons per year, as opposed to 14.2 metric tons per year before the desistance rate was zeroed out. The difference, 4.8 metric tons per year, is the in-treatment effect and it is 34 percent of the total treatment effect.

The importance of the in-treatment effect highlights an interesting contrast between criminal-justice research and drug research approaches to analyzing program effectiveness. Discussions of how prison affects crime tend to emphasize incapacitation ("in-treatment effect") and implicitly assume that rehabilitation ("after-treatment effects") may be too small to matter very much.[7] In contrast, discussions of drug treatments tend to emphasize the proportion of people treated who stop using drugs, and it is the in-treatment effect that is usually (incorrectly, as it turns out) implicitly assumed to be too small too matter.[8]

Turning to the consumption decrease that can be achieved per treatment-program dollar, Table 3.2 replicates Table 2.1 to facilitate comparisons with supply-control programs. As before, the cocaine-control model is run to find the control cost in the first projection year that results in a stream of consumption reductions over 15 years whose present value is 1 percent of total consumption in the first projection year. The cost of the necessary amount of treatment is $34 million. This is much less than the cost of achieving the consumption reduction through supply controls. The least expensive supply-control program, domestic enforcement, costs 7.3 times more than treatment (see Table 3.2 and Figure 3.8).

The $34 million estimate reflects two factors. First, most users stay off drugs while in treatment. The average cocaine treatment costs $1,740 per person treated, so $34 million pays for 19,500 treatments of heavy users. The average treatment lasts 0.30 years, and 80 percent of the people in treatment are off drugs, so the in-treatment effect of 19,500 treatments is about 5,000 person-years less heavy cocaine use, which (at 120 grams per heavy user per year) amounts to 0.6 metric tons less cocaine consumption.

Table 3.2

Effect of Control Programs on Cocaine Consumption

Control Program	Cost of 1% Decrease in Cocaine Consumption ($ millions/yr)	Program Cost Relative to Treatment
Source-country control	783	23.0
Interdiction	366	10.8
Domestic enforcement	248	7.3
Treatment	34	1.0

NOTE: These costs are the additional control costs in the first projection year which result in consumption decreases over 15 projection years that have a net present value equal to 1 percent of the first year's consumption.

[7]See, for example, Nagin (1978, p.92), who concludes that high recidivism means that rehabilitation does not occur.

[8]See, for example, Wallace (1990), Washton and Stone-Washton (1990), and Washton and Stone-Washton (1991), all of which discuss the problem of many people returning to drug use after treatment, so that multiple treatments are required, but do not discuss the benefit of the in-treatment effect. In addition, the extensive review of drug treatment programs in Anglin and Hser (1990) focuses on comparing post-treatment drug use with pre-treatment drug use. No mention is made of reduction in drug use during treatment as a program benefit.

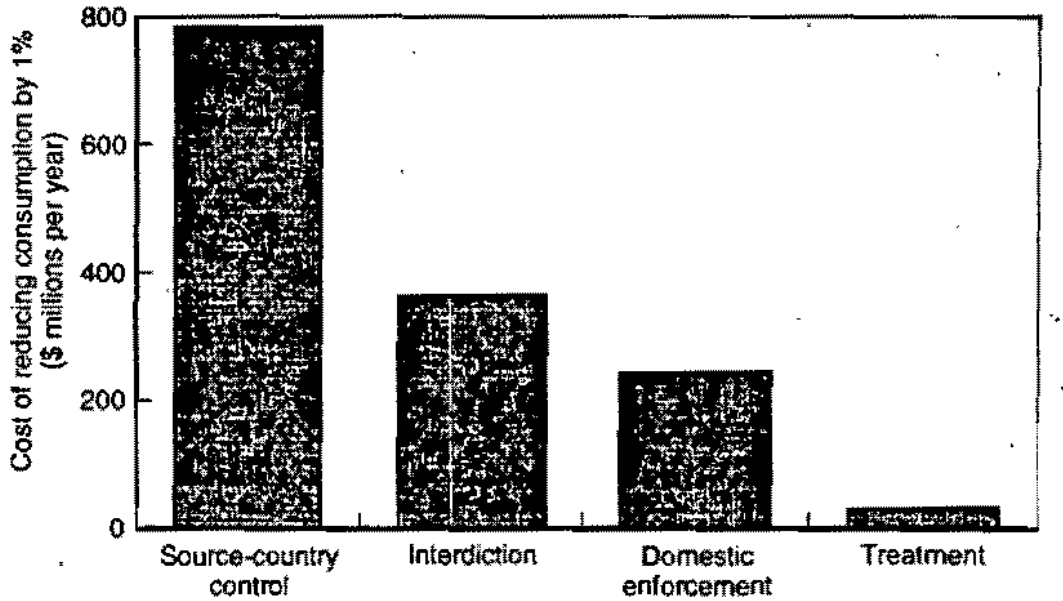

Figure 3.8—Cost of Reducing Cocaine Consumption by 1 Percent with Alternative Cocaine-Control Programs

Second, some users stay off drugs after treatment. An estimated 13 percent of heavy users treated do not return to heavy use after treatment. Not all those departures are permanent, however. Nevertheless, during the 14 years following treatment, the 19,500 treatments would generate an estimated present value of 20,000 person-years less heavy cocaine use, which amounts to 2.4 metric tons less cocaine consumption. When we add the 0.6 metric ton in-treatment reduction to the 2.4 metric ton after-treatment reduction, we find that 19,500 additional treatments would reduce cocaine consumption by an amount equal to 1 percent of the 300 metric tons currently consumed annually.

Supply- and demand-control programs differ not only in the cost of achieving a 1 percent reduction in consumption, but also in how they achieve that reduction (see Table 3.3). Supply control reduces the numbers of both light and heavy users, while treatment primarily reduces the number of heavy users.

An even more dramatic difference is that supply control increases user spending on cocaine, while treatment decreases it. Additional supply control causes percentage increases in price that are larger in absolute value than the percentage decreases in consumption, so user spending on cocaine increases. In contrast, additional treatment causes only small increases in price,[9] so there is essentially no offset to the decreases in consumption, and user spending on cocaine decreases.

[9]That treatment should affect price at all, let alone positively, requires some explanation. As additional treatment reduces consumption, existing supply-control sanctions get spread over a smaller volume of business, causing the sanction per unit product, and hence the retail price, to increase. (See the discussion of the downward slope of the industry supply curve in Appendix E.)

Table 3.3

Other Consequences of Additional Control that Reduces Cocaine Consumption by 1 Percent

	Percent Changes in:				
Control Program	Light Users	Heavy Users	All Users	Price of Cocaine	Spending on Cocaine
Supply control[a]	−0.33	−0.50	−0.37	2.0	1.0
Treatment	−0.05	−1.08	−0.22	0.3	−0.7

NOTE: These percentages are the net present value of changes over 15 projection years relative to the first projection year's total.

[a]All three supply-control programs behave the same on these outcomes for an expenditure that reduces consumption by 1 percent.

The summary measure used so far in this analysis—the current cost of achieving an over-time reduction in consumption amounting to 1 percent of current consumption—is appropriate for comparing program cost-effectiveness, but it obscures the dynamics of program effects. To provide a look at those dynamics, Figure 3.9 plots the results of adding $1 billion to the current $13.0 billion annual cocaine-control budget,[10] allocating it equally to all four control programs. That is, each program gets $250 million added to its annual budget. To construct the graph, the program additions are done cumulatively. This is in contrasr to the analysis in Table 3.2, where the program budgets are modified independently.

Figure 3.9 shows that even though the budget additions are uniform over time (each year's budget for a given program is $250 million more that it would have been without the change), the effect on consumption is far from uniform. Rather, there is an immediate decrease in consumption during the first year, reflecting the price effect (of the supply-control programs) and the in-treatment effect (of the treatment programs) on current consumption. Then the remaining decrease in consumption accumulates over time as the effect of both supply-control and treatment programs on user flows gradually changes the number of cocaine users.

As the graph shows, spending $250 million on treatment each year results in a 27 metric ton reduction in consumption by the year 2007.[11] This reduction is considerably larger than the 6 metric ton total reduction in consumption by 2007 accomplished by spending $750 million per year on supply control ($250 million each year on each of the three supply-control programs).

The bottom line explanation for the consumption reduction due to treatment is that at $1,740 per average treatment, $250 million buys 144,000 additional treatments per

[10]The estimated $13.0 billion expenditure on cocaine control during 1992 consisted of $0.9 billion spent on source-country control, $1.7 billion spent on interdiction, and $9.5 billion spent on domestic enforcement (all levels of government) (see Table B.8 in Appendix B), plus $0.9 billion spent on treatment (both public and private) (see Tables D.1 and D.2 in Appendix D).

[11]Interaction among programs is negligible in this example. In Figure 3.8, the treatment budget is increased only after increasing all the supply-control budgets. However, the same 27 metric ton reduction by 2007 occurs if the treatment budget is increased before the supply-control budgets.

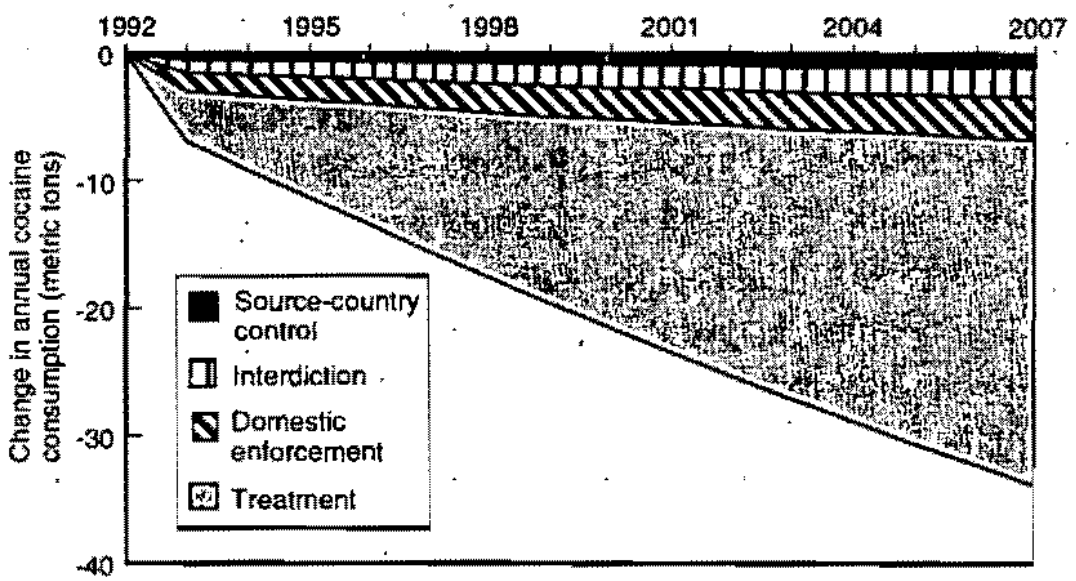

Figure 3.9—Dynamics of Consumption Change if $250 Million Is Added to Each Program's Annual Budget

year. Thirteen percent of the heavy users treated, or about 19,000 people, flow out of heavy cocaine use as a result of the treatment. If all stayed off cocaine permanently, then over 15 years, the reduction in heavy users would accumulate to 285,000. However, some of the departures from heavy use are temporary, so the estimated net reduction in heavy users by 2007 is only 225,000. At an average use of 120 grams per year per heavy user, this amounts to a 27 metric ton reduction in annual cocaine consumption.

Chapter Four

SENSITIVITY TO KEY PARAMETERS

The responsiveness of cocaine consumption to the price of cocaine and the additional outflow from heavy cocaine use due to treatment are the two most important behavioral parameters determining this study's conclusion that treatment is more cost-effective than supply control. This chapter shows that the conclusion remains true even if these parameters should differ greatly from the values used in this analysis. The analysis considers both independent and joint effects of these parameters.[1]

PARAMETERS ANALYZED

The *price elasticity of demand* is the percentage change in demand caused by a 1 percent increase in the retail price of cocaine.[2] This parameter is the fundamental link between supply-control programs and consumption. Supply-control programs increase the retail price of cocaine, and that price increase causes consumption to decrease, with the amount of the consumption decrease determined by the price elasticity of demand.[3]

The *additional outflow due to treatment* is the percentage of heavy users treated during a year that stop heavy use of cocaine during the year because of the treatment. They may regress to light use or they may stop cocaine use altogether, but they are no longer heavy users.[4] This percentage is in addition to the percentage of those in treatment who would have quit during the year without treatment. Moreover, the dynamic model of cocaine demand recognizes the possibility that some people who flow out of heavy cocaine use in one year may flow back in a future year.

---

[1]Appendix F analyzes the effect of varying additional parameters in the cocaine-control model.

[2]Demand decreases when price increases, so this price elasticity is a negative number. In this chapter, it is convenient to have positive values to graph, so the figures plot the absolute value of the price elasticity.

[3]For the precise role that the price elasticity of demand plays in the cocaine-control model, see the parameter e in Eqs. C.4 through C.10 in Appendix C.

[4]The added outflow due to treatment is a weighted average of the outflows due to outpatient and residential treatment. The sensitivity analysis is done with a parameter x that is a multiplier times the average outflow rate (12.5 percent in the reference situation). For the best estimate of the outflow rate, $x = 1.0$; for the low estimate, $x = 0.75$; for the high estimate, $x = 1.50$ (see Eq. (D.3) in Appendix D).

UNCERTAINTY RANGES

The ranges for the sensitivity analysis are presented in Table 4.1. The middle value is labeled "best," indicating that it is the best estimate that could be obtained for this analysis. The low and high values define ranges judged by the authors to include all parameter values that have a reasonable chance of being the correct value. If a new study of one of these parameters were conducted tomorrow and the result fell within the indicated range, we would not be surprised.

Table 4.1

Ranges for Sensitivity Analysis

	Parameter Value		
Parameter	Low	Best	High
Price elasticity of demand	−0.38	−0.50	−0.75
Additional outflow due to treatment (%)	9.9	13.2	16.5

SENSITIVITY RESULTS

Tables 4.2 and 4.3 present the results of the sensitivity analysis of these parameters. The heading of each table shows the parameter and gives the low, best, and high values of it. The body of each table gives the estimated annual costs (in millions of 1992 dollars) of reducing cocaine consumption by 1 percent,[5] for given control programs and given values of the parameter in question. The bottom row of each table gives the ratio of the cost of achieving the consumption reduction through domestic enforcement to the cost of achieving it through treatment.

Table 4.2

Cost of Reducing Consumption by 1 Percent: Effect of Price Elasticity of Demand
($ millions per year)

	Price Elasticity of Demand		
Control Program	−0.38	−0.50	−0.75
Source-country seizures	1084	783	474
Interdiction	505	366	222
Domestic enforcement	330	246	154
Treatment of heavy users	35	34	31
Enforcement/treatment	9.5	7.3	5.0

[5]As in Chapters Two and Three, this is the cost in the first projection year of achieving consumption reductions over 15 projection years whose net present value is 1 percent of consumption in the first projection year.

Table 4.3

Cost of Reducing Consumption by 1 Percent: Effect of Additional Outflow Due to Treatment
($ millions per year)

	Additional Outflow Due to Treatment (%)		
Control Program	9.9	13.2	16.5
Source-country seizures	796	783	771
Interdiction	372	366	360
Domestic Enforcement	250	246	242
Treatment of heavy users	43	34	27
Enforcement/treatment	5.7	7.3	9.0

The ratio in the bottom row of these tables is always greater than 1.0 (substantially greater). This means that even when these parameters are varied to the extremes of their uncertainty ranges, treatment remains more cost-effective than domestic enforcement. Also, the ranking of costs down the columns is always the same. Source-country control costs more than interdiction, which costs more than domestic enforcement, which costs more than treatment.

Thus, the main qualitative results of this analysis are not affected by uncertainty about these parameter values. However, the specific estimates of the program costs necessary to achieve given consumption cuts certainly are affected. These sensitivity-analysis tables give a useful indication of just how far to push (or, rather, how far not to push) the findings of this analysis.

INTERACTION EFFECTS

The effects of varying the two parameters, price elasticity of demand and additional outflow due to treatment, are not completely independent. Rather, there is some interaction (see Table 4.4). When the parameters change in the direction of favoring enforcement, the effects partially cancel. For example, when the price elasticity changes from –0.50 to –0.75, the cost of enforcement relative to treatment decreases by 2.3 (from 7.3 to 5.0); and when the additional outflow changes from 13.2 percent to 9.9 percent, the cost of enforcement relative to treatment decreases by 1.6 (from 7.3 to 5.6). However, when both parameter changes occur, the joint effect is not the sum of these independent effects, –3.9, but rather the smaller change of –3.4.

On the other hand, when the parameters change in the direction of favoring treatment, the effects reenforce each other. For example, when the price elasticity changes from –0.50 to –0.38, the cost of enforcement relative to treatment increases by 2.2 (from 7.3 to 9.5); and when the additional outflow changes from 13.2 percent to 16.5 percent, the cost of enforcement relative to treatment increases by 1.7 (from 7.3 to 9.0). When both parameter changes occur, the joint effect is not the sum of these independent effects, 3.9, but rather the larger change of 4.4.

Table 4.4

Effect of Joint Variation of Parameters

Additional Outflow Due to Treatment	Price Elasticity of Demand −0.38	−0.50	−0.75
Cost of Domestic Enforcement Relative to Treatment			
16.5	11.7	9.0	6.1
13.2	9.5	7.3	5.0
9.9	7.4	5.7	3.9
Difference from 7.3			
16.5	4.4	1.7	−1.2
13.2	2.2	0.0	−2.3
9.9	0.1	−1.6	−3.4
Relative Difference from 7.3			
16.5	0.60	0.23	−0.16
13.2	0.30	0.00	−0.32
9.9	0.01	−0.22	−0.47

The simplest way to describe what is going on is that when the changes are expressed as proportions, the interaction effect is multiplicative, as in the identity $(1 + a)(1 + b) = 1 + a + b + ab$. So two negative changes result in a positive interaction term that partially cancels the independent effects, while two positive changes also result in a positive interaction term that reenforces the independent effects. For example, $(1 - 0.32)(1 - 0.22) = 1 - 0.32 - 0.22 + 0.07 = 1 - 0.47$; and $(1 + 0.30)(1 + 0.23) = 1 + 0.30 + 0.23 + 0.07 = 1 + 0.60$.

THRESHOLD ANALYSIS

The above sensitivity analyses establish ranges over which parameters can vary and then ask how much that variation affects results. "Threshold analysis" poses the opposite question: It asks what parameter changes are necessary to reach the boundary where the outcome changes qualitatively. Specifically, under what circumstances would domestic enforcement become as cost-effective as treatment?

Varying the parameters over wide ranges one at a time does not find such a threshold. Increasing the absolute value of the price elasticity of demand reduces the gap between the cost-effectiveness of domestic enforcement and that of treatment, but the crossover point is not reached even if the absolute value of the price elasticity is as large as 2.0 (see Figure 4.1). Decreasing the additional outflow due to treatment reduces the gap between the cost-effectiveness of domestic enforcement and that of treatment, but the crossover point is not reached even if the additional outflow is zero (see Figure 4.2). This last finding shows that, by itself, the suppression of cocaine use while people are in treatment reduces cocaine consumption enough to make treatment more cost-effective than domestic enforcement.

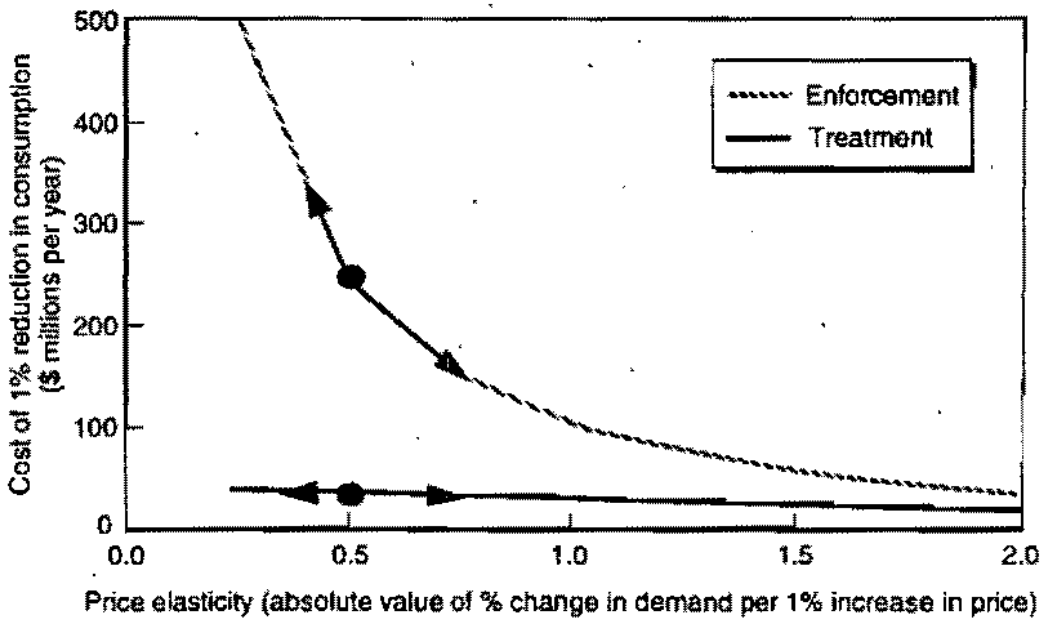

Figure 4.1—Effect of Price Elasticity of Demand on Cost of Achieving a 1 Percent Reduction in Consumption

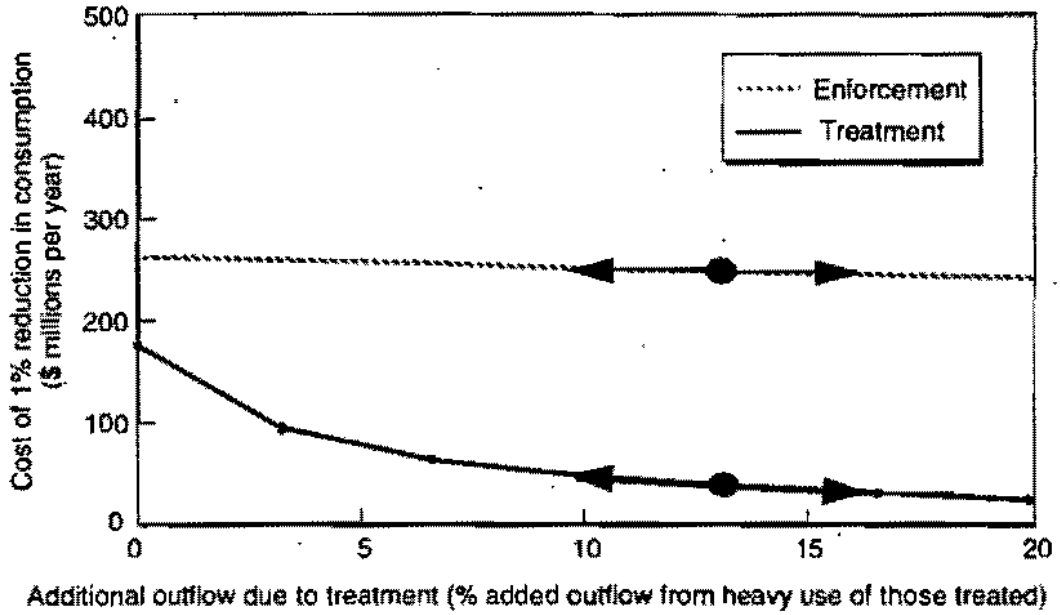

Figure 4.2—Effect of Additional Outflow Due to Treatment on Cost of Achieving a 1 Percent Reduction in Consumption

In both figures, solid dots indicate our best estimates of parameter values (price elasticity −0.5, additional outflow 13.2 percent). The arrows indicate the sensitivity ranges analyzed above (price elasticity being between −0.38 and −0.75, and additional outflow being between 9.9 percent and 16.5 percent).

Varying the parameters jointly does identify a threshold beyond which domestic enforcement is more cost-effective than treatment, but that threshold is very distant from our best understanding of these parameter values (see Figure 4.3). For domestic enforcement to be more cost-effective than treatment, price elasticity must be sufficiently high and added outflow must be sufficiently low that together they exceed the diagonal-line threshold in the upper left corner of Figure 4.3.

The solid dot in the diagram indicates the parameter values used in this analysis. The arrows leading out from the dot show the ranges in the sensitivity analysis. The cross formed by the arrows shows the uncertainty range of the parameters. The small size of the cross relative to the distance from the dot to the threshold line shows the robustness of the conclusion that treatment is the most cost-effective cocaine-control program.

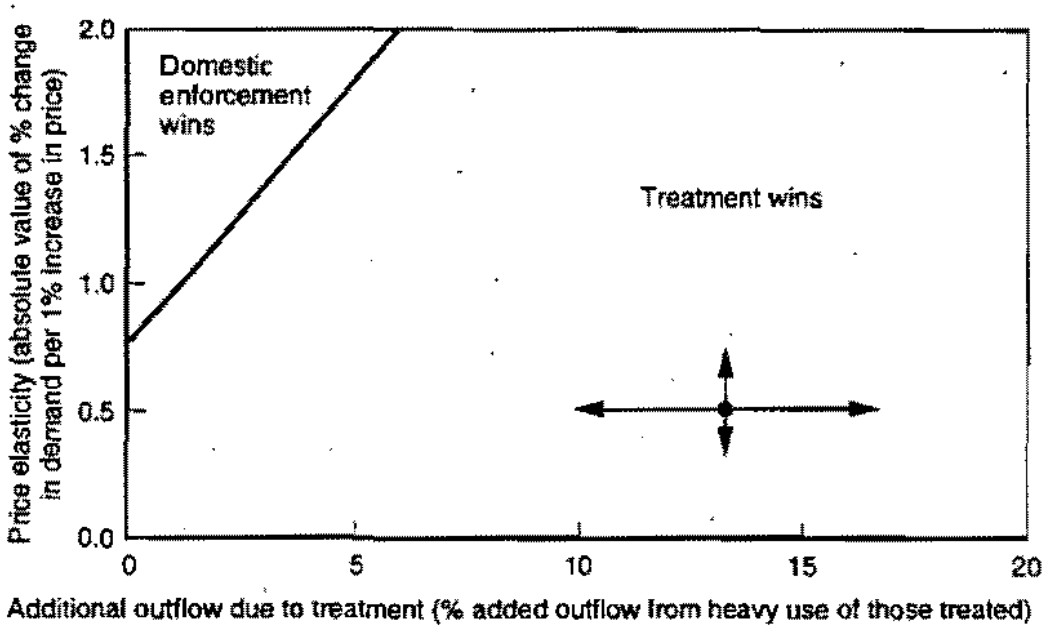

Figure 4.3—Threshold Values of Price Elasticity and Additional Outflow, Where Domestic Enforcement Becomes More Cost-Effective Than Treatment

Chapter Five

ALTERNATIVE EVALUATION CRITERIA

This chapter considers two criteria for evaluating cocaine-control programs that are alternatives to the consumption criterion used so far in this report. In a sense, this discussion is a continuation of the previous chapter's sensitivity analysis, except that instead of varying input parameters, we now vary output measures. The two alternative evaluation criteria are:

- Number of people using cocaine.
- Cost of crime and lost productivity due to cocaine use.

User counts are often used to measure the size of the cocaine problem because they are readily available (and widely publicized) from the National Household Survey on Drug Abuse, conducted annually by the National Institute on Drug Abuse (NIDA). This measure, however, has the defect that it does not recognize that intensity of cocaine use varies greatly across users. The consumption measure used throughout this report corrects for that defect by weighting light- and heavy-user counts by estimated consumption rates.

Of course, we would like to evaluate programs with a measure of the harm done to society by cocaine use. In particular, we would like a measure that distinguishes between societal effects of increased consumption of cocaine by users (lost productivity due to the debilitating effects of drug use) and the societal effects of increased expenditure on drugs by users (increased crime by users to raise the money for drugs, and increased violence by dealers to protect drug profits).

This chapter constructs such a societal cost measure. However, consumption is used as the main evaluation criterion in our analysis, because we judge that the state of the art of harm measurement is not yet advanced enough to be persuasive by itself. The societal cost estimates are offered here merely as additional information with which to compare the alternative control programs.

The central purpose of considering these alternative evaluation criteria is to see whether they contradict the program rankings established by the consumption criterion. The conclusion is that they do not change the earlier result. On all three evaluation criteria (users, consumption, and societal costs), interdiction is more cost-effective than source-country control, domestic enforcement is more cost-

effective than interdiction, and treatment of heavy users is more cost-effective than any of the supply-control programs.

NUMBER OF COCAINE USERS

Table 5.1 does for users what Table 3.2 in Chapter Three did for consumption. The reported costs are what must be added to the first projection-year budgets of each control program to reduce user counts over 15 years by amounts whose present value is 1 percent of the total number of users in the first projection year.

Comparing the results for users with the earlier results for consumption shows that the patterns are similar (see Figure 5.1). In both cases the budget required for the 1 percent reduction gets smaller as one moves from source-country control, to interdiction, to domestic enforcement, and finally to treatment.

However, the cost levels differ. In every control program the cost for a 1 percent reduction in users is much larger than the cost for a 1 percent reduction in consumption. Decreasing the number of cocaine users by a given percentage costs more than decreasing cocaine consumption by that percentage because control programs influence consumption both directly, through the consumption of current levels of users, and indirectly, through altering the flows of users into and out of cocaine use, while control programs influence the number of users only through the indirect effect on flows. Because control programs attack user counts in fewer ways than they attack consumption, achieving a given percentage reduction costs more.

SOCIETAL COSTS

Our societal-cost measure includes the cost of crime due to cocaine use and the cost of lost productivity due to cocaine use. The cost of crime includes criminal-justice system costs as well as property and victim costs. The cost of lost productivity includes health-care system costs, as well as individual and collective costs of reduced user capabilties.

Table 5.1

Effect of Control Programs on Number of Cocaine Users

Control Program	Cost of 1% Decrease in Cocaine Users ($ millions/yr)	Ratio of Program Cost to Treatment Cost
Source-country control	2,062	13.3
Interdiction	964	6.2
Domestic enforcement	675	4.4
Treatment	155	1.0

NOTE: These costs are the additional control costs in the first projection year which result in user count decreases over 15 projection years that have a net present value equal to 1 percent of the first year's user count.

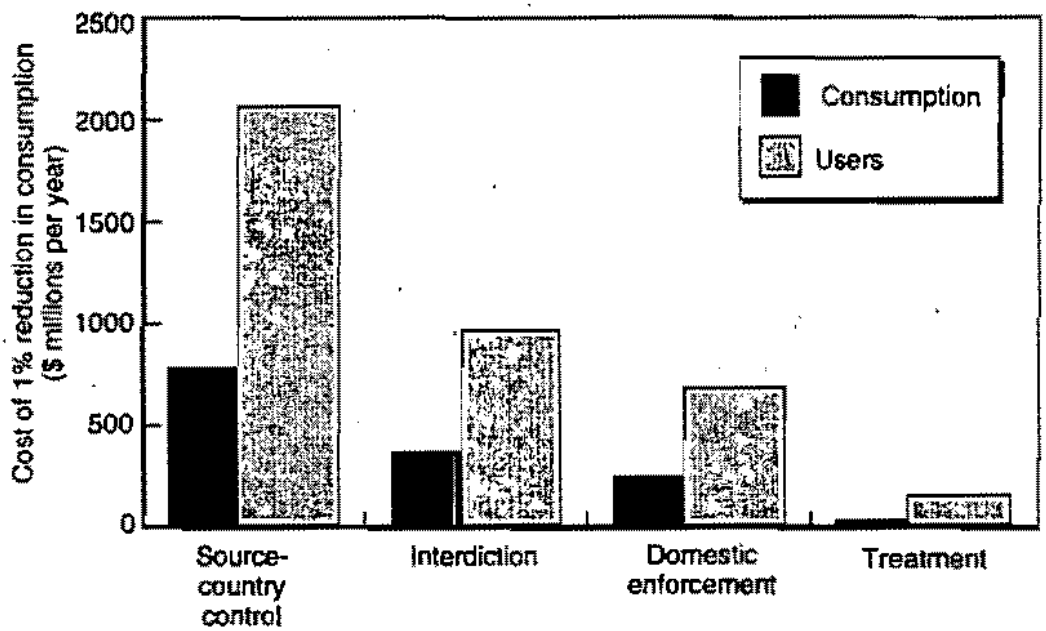

Figure 5.1—Costs of Reducing Users by 1 Percent vs. Costs of Reducing Consumption by 1 Percent

The key point about this measure is that the crime and productivity-loss components can move in opposite directions. Our analysis assumes that user expenditure on cocaine tends to increase crime and that user consumption of cocaine tends to increase productivity losses. For supply-control programs, the two components in societal costs partially offset each other, because those programs increase user expenditure while decreasing user consumption. On the other hand, for treatment, the two components of societal costs reenforce each other, because treatment decreases both user expenditure and user consumption.

Appropriately, the societal-cost measure does not include the cost of supply-control programs or the cost of treatment programs—those costs are captured by the cocaine-control budget. Of course, the total cost to society due to cocaine is the sum of the crime and productivity costs and the control costs. For an increase in cocaine control to reduce the total cost to society, the savings in crime and productivity costs must be greater than the increase in control costs.

How Large Are the Societal Costs of Cocaine?

Table 5.2 presents estimates of the societal costs of cocaine use based on the Rice et al. (1990) estimates of the costs of drug abuse. Details for each summary category (crime and lost productivity) in the table show how the aggregate estimates were

Table 5.2

Estimates of Annual Crime and Lost-Productivity Costs Due to Cocaine Use

Type of Cost	1985 Cost of Drug Abuse ($ millions)	Adjustment Factor, 1985 to 1988[a]	Adjustment Factor, 1988 to 1992[b]	Proportion Cocaine[c]	1992 Cost of Cocaine Abuse ($ millions)[d]
		Crime Due to Drug Abuse			
Property destruction	759	1.320	1.185	0.433	514
Victims of crime	842	1.320	1.185	0.433	570
Criminal justice	9,508	1.279	1.185	0.433	6,240
Subtotal	11,109				7,324
		Productivity Lost Due to Drug Abuse			
Short hospital stay	1,242	1.305	1.185	0.373	716
Morbidity	5,979	1.203	1.185	0.373	3,179
Mortality[e]	9,605	1.188	1.185	0.373	5,044
Incarceration	4,434	1.320	1.185	0.373	2,587
Crime career	13,976	1.320	1.185	0.373	8,154
Subtotal	35,236				19,680

SOURCE: Rice et al. (1990, pp. 8, 132, 146, 164).

NOTE: Does not include alcohol abuse or control-program costs.

[a]Adjustment from 1985 to 1988 done with Rice report factors (Rice, 1990, p. 164).

[b]Adjustment from 1988 to 1992 done with Consumer Price Index (CPI).

[c]Fraction of crime costs caused by cocaine is estimated by cocaine's proportion of user expenditure on all drugs (ONDCP, 1991b, p. 5).

[d]Fraction of productivity cost caused by cocaine is estimated by cocaine's proportion of all drug-abuse treatments (Burynski, 1990, pp. 41–42). The assumption is that the severity of the problem caused by a drug, relative to other drugs, is proportional to the number of drug users who seek treatment.

[e]Mortality cost estimate for all drug abuse is 6,118 deaths (Rice, 1990, p. 132) times $1.57 million per death (Fisher, Chestnut, and Violette, 1989, p. 97, estimate expressed in 1985 dollars).

constructed. Also, the table shows the adjustments made to inflate the drug-abuse cost estimates to 1992 and to identify cocaine's share of the total cost.

Crime costs consist of three detailed categories estimated by Rice: "Property destruction" includes all property lost due to violent and personal crimes such as robbery, assault, burglary, larceny, and motor vehicle theft. "Victims of crime" consists of the cost of lost work time by those who are victimized. "Criminal justice" costs are the arrest costs and jail or prison costs for people apprehended committing crimes to support their drug habit.

Productivity-loss costs are divided into five detailed categories estimated by Rice: "Short hospital stay" includes emergency room visits, but does not include outpatient or residential drug treatments. "Morbidity" costs are the value of goods and services lost because cocaine users produce less—either because they are unable to perform their usual activities at full effectiveness or because they are unable to perform their usual activities at all. "Mortality" costs are the current monetary value of future output lost due to premature death. "Incarceration" costs are the productivity losses for individuals in prison as a result of a conviction for a drug-related crime.

"Crime career" costs are the productivity losses for drug users who engage in crime as a career rather than in legal employment.[1]

How Do Control Programs Affect the Societal Costs?

Two assumptions govern our estimates of how cocaine-control programs affect societal costs:

- The cost to society of crime caused by cocaine use is proportional to the expenditure on cocaine by cocaine users,
- The cost to society of productivity losses caused by cocaine use is proportional to the consumption of cocaine by cocaine users.

The need for evidence that supports these assumptions (or that replaces them with better assumptions) is the major deficiency in the current state of the art of harm measurement. On the other hand, considerable variation can be made in these assumptions without changing the qualitative findings below.

Table 5.3 does for societal costs what Table 3.7 in Chapter Three did for consumption, and what Table 5.1 earlier in this chapter did for users. Once again, the first projection-year budgets of each control program are increased, but this time the objective is to make 15 years of reductions in societal costs have a net present value equal to 1 percent of the societal costs in the first projection year.

As in the analysis of user counts, we compare the results for societal costs with the earlier results for consumption (see Figure 5.2). The by-now-familiar result is that the incremental budget required for the 1 percent reduction becomes smaller as one moves from source-country control, to interdiction, to domestic enforcement, and finally to treatment.

Table 5.3

Effect of Control Programs on Cost of Crime and Lost Productivity

Control Program	Cost of 1% Decrease in Societal Cost ($ millions/yr)	Program Cost Relative to Treatment
Source-country control	1904	51.4
Interdiction	890	24.1
Domestic enforcement	540	14.6
Treatment	37	1.0

NOTE: These costs are the additional control costs in the first projection year which result in societal cost decreases over 15 projection years that have a net present value equal to 1 percent of the first year's societal cost.

[1] Incarceration costs and crime career costs are included under the lost-productivity heading rather than the cost of crime, because we assume that they are dependent primarily upon the cocaine-caused inability to do productive work in society, rather than on the amount of crime committed. Hence they are assumed to be driven by the amount of cocaine consumed, rather than by the cost of purchasing the cocaine.

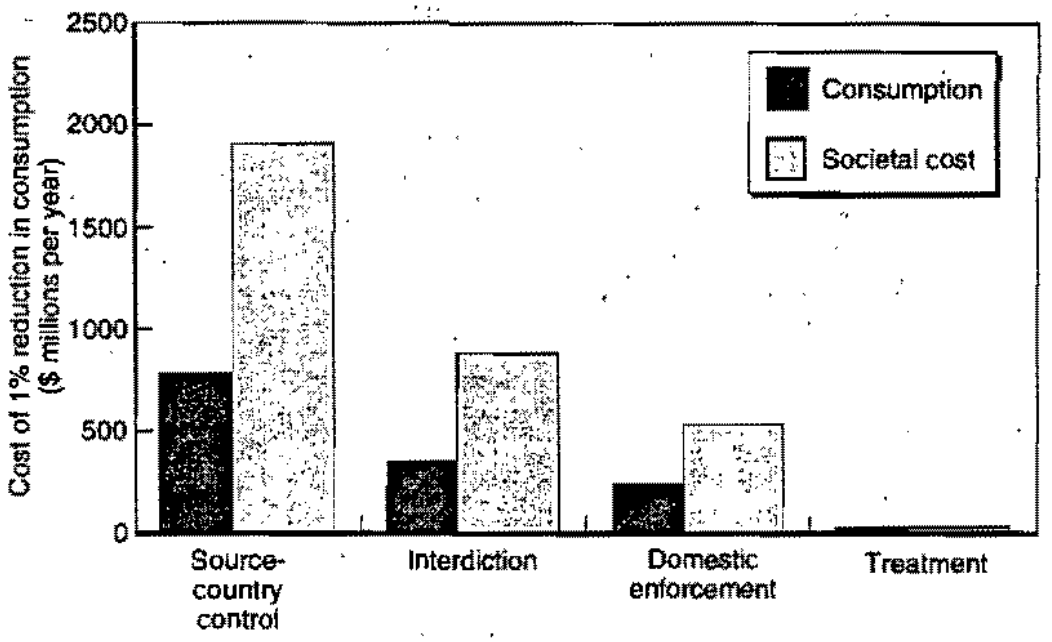

Figure 5.2—Costs of Reducing Societal Costs by 1 Percent vs. Costs of Reducing Consumption by 1 Percent

This time, however, the cost levels differ only for the supply-control programs. The cost of a 1 percent reduction in societal cost is essentially the same as that of a 1 percent reduction in consumption. The supply-control programs are relatively less effective at reducing societal costs because they march in two directions: The price increase that causes consumption (and hence the cost of lost productivity) to decrease also causes user expenditure on cocaine (and hence the cost of crime) to increase.

Note that this partial canceling of the effect of supply controls on societal costs is dependent upon the price elasticity of demand having an absolute value less than 1.0. Since we judge that elasticity to be –0.5, we are well within that limit. When supply control causes a 1 percent increase in the price of cocaine, consumption of cocaine decreases by 0.5 percent—making user expenditure on cocaine increase by 0.5 percent.

We have compared the costs of reducing user counts with those of reducing consumption, and the costs of reducing societal costs with those of reducing consumption. Now, we make a three-way comparison. Figure 5.3 plots the ratio of domestic enforcement cost to treatment cost for 1 percent reductions in each criterion. The trend is dramatic. Moving to more sophisticated measures of program effectiveness increases the cost-effectiveness advantages of treatment.

Finally, the societal-cost analysis offers the opportunity to go beyond judging *relative* program performance and also judge *absolute* performance.[2] Societal cost is mea-

[2]The assessment is fairly broad brush, however, given the limitations of our knowledge of the societal costs of cocaine.

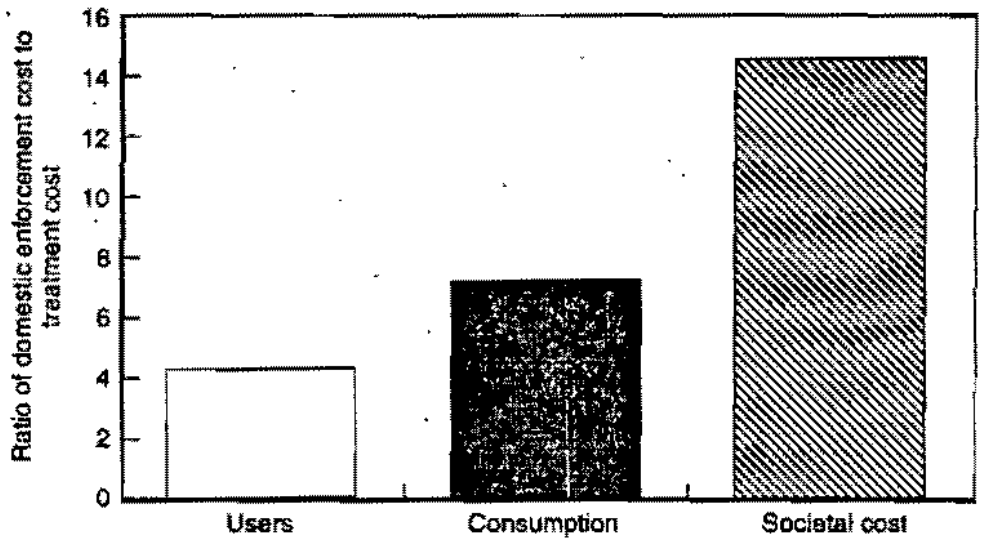

Figure 5.3—Cost of Domestic Enforcement Relative to Treatment Under Alternative Evaluation Criteria

sured in dollars, as are the control-program budgets, so we can compare the two and ask whether the savings in societal costs are larger or smaller than the control-program budgets required to obtain those savings.

Figure 5.4 shows our answer to the absolute cost-effectiveness question. For the supply-control programs, the estimated savings are smaller than the control costs:

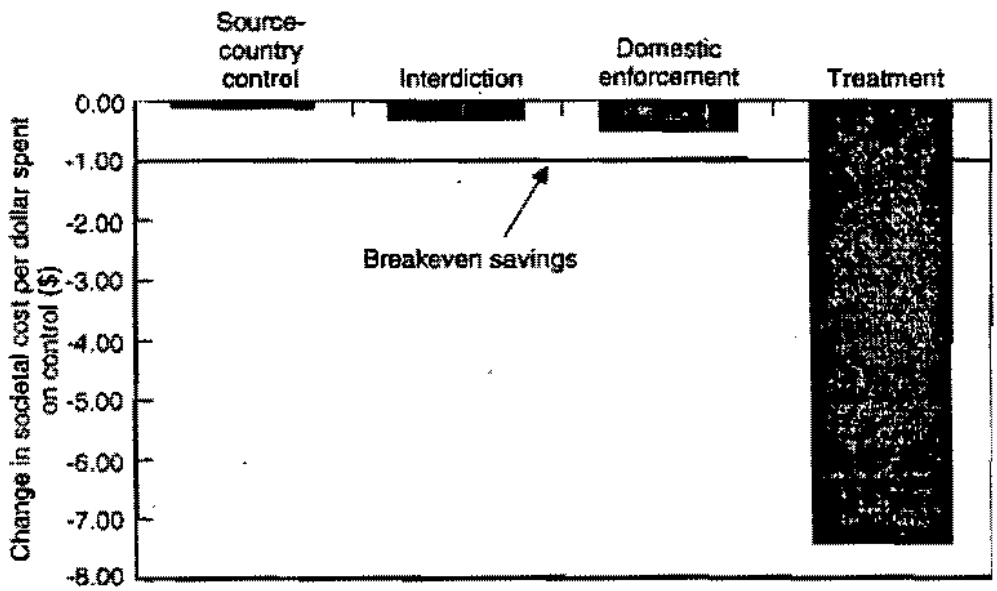

Figure 5.4—Savings in Societal Costs Resulting from Alternative Control Programs

An additional cocaine-control dollar generates societal cost savings of 15 cents if used for source-country control, 32 cents if used for interdiction, and 52 cents if used for domestic enforcement. In contrast, the savings from treatment programs are larger than control costs: an additional cocaine-control dollar generates societal cost savings of $7.48 if used for treatment.

Chapter Six

COMPOSITE PROGRAMS

The previous chapters of this report focused on finding the direction in which cocaine-control policy could move to become more cost-effective. The answer was to cut back on supply control and expand treatment of heavy users. However, there remains the question of how far one can move in this indicated direction. There is a limit to how much of the cocaine problem can be solved by treatment, because treatment is only partially successful in stopping cocaine use. Even treating all heavy users once a year would not eliminate the cocaine problem.

This final chapter explores what can be accomplished by expanding treatment, both with and without cuts in supply control. Specifically, we analyze four alternatives to current policy:

- **Alternative A:** decrease each of the three supply-control program budgets by 25 percent.
- **Alternative B:** decrease the supply-control budgets by 25 percent and double the current treatment budget.
- **Alternative C:** decrease the supply control budgets by 25 percent and treat 100 percent of heavy users each year.
- **Alternative D:** treat 100 percent of heavy users each year without changing the supply-control budget.

Table 6.1 shows the cocaine-control budgets for each alternative. The supply-control budgets are 25 percent below current policy for Alternatives A through C, and the same as current policy in Alternative D.[1] The treatment budget is twice that of current policy in Alternative B, and almost four times current policy in Alternatives C and D.

Neither the number of treatments nor the percentage of heavy users treated doubles when the treatment budget doubles, because we assume that the proportion of residential treatments relative to outpatient treatments increases as more people are treated. For example, comparing Alternative B with current policy, although the

[1]The 25 percent cut was chosen for this analysis because it is a round number that generates enough control-budget savings to pay for treating all heavy users once a year.

Table 6.1

Characteristics of Alternative Composite Plans

Item	Current Policy	Alternative Plans: 25% Cut Supply Control (A)	Double Treatment (B)	100% Treatment (C)	Restore Supply Control (D)
Cocaine Control Budgets ($ billions per year)					
Source-country control	0.87	0.65	0.65	0.65	0.87
Interdiction	1.71	1.28	1.28	1.28	1.71
Supply control	9.47	7.11	7.11	7.11	9.47
Treatment	0.93	0.93	1.86	3.68	3.52
Total	12.98	9.97	10.90	12.72	15.57
Number of Treatments per Year (thousands)					
Outpatient treatment	430	434	610	627	600
Residential treatment	118	117	272	627	600
Total	548	551	882	1253	1200
Percent Heavy Users Treated Each Year					
Percent treated	29	27	51	100	100

NOTE: Alternative A cuts all three supply-control program budgets by 25 percent; Alternative B spends one-third of the supply-control savings on doubling the current treatment budget; Alternative C spends nearly all the supply-control savings to treat 100 percent of the heavy users each year; and Alternative D treats 100 percent of the heavy users each year, with no cut in the supply-control budget. Estimates are annualized values over 15 projection years using a 4 percent real discount rate. All dollar values are expressed in 1992 dollars.

treatment budget is double, the number of treatments is only three-fifths greater, and the percentage of heavy users treated is only four-fifths greater.[2]

Alternatives C and D, the "100 percent treatment" plans, offer treatment during a year to all people who are heavy cocaine users at the start of the year. Beyond this point, treatment most likely cannot go. In fact, it is not at all certain that this level of treatment is feasible. Keep in mind, however, that the percentage refers to the number of treatments during a year divided by the number of heavy users at the start of the year. If a person who is offered treatment quits after only a week or so, and then a few months later starts treatment again and this time goes the distance, that counts as two treatments even though there is only one person involved and the first treatment essentially did not happen. So the number of separate people treated during a year would be less than 100 percent of the heavy users, and the number of people who receive complete treatments would be an even smaller proportion of all heavy users. Looked at this way, the "100 percent treatment" alternatives appear more feasible than they do at first glance.

[2]The percentage treated increases more than the number of treatments because Alternative B decreases the number of heavy users. Also, the treatment percentage is of heavy users at the start of a year. This differs somewhat from treatment as a percentage of the heavy users at the end of a year reported below in Table 6.2.

What do these four alternative composite plans accomplish? Figure 6.1 shows that they offer a range of cocaine-consumption levels in return for varying amounts of cocaine-control money.

If supply-control budgets are cut by 25 percent (Alternative A), the cocaine problem (as measured by consumption) gets worse, but the cocaine-control budget decreases. However, spending about half of the supply-control savings on doubling treatment (Alternative B) reduces cocaine consumption below what would occur under current policy. Expanding treatment to all the heavy users (Alternative C) further reduces consumption and uses up essentially all the savings from the supply-control cut. Finally, if all the heavy users are treated without cutting the supply-control budget (Alternative D), consumption decreases even more, but the control budget is one-fifth higher than it is under current policy.

The composite programs plotted in Figure 6.1 are, of course, not the only alternatives to current policy. For example, initially cutting supply-control programs by a greater percentage would shift point A leftward (and slightly upward) and move the entire curve (excepr for point D) generally to the left.

Moreover, even retaining the 25 percent cuts in supply control, there are intermediate plans between those analyzed here. Any place on the bold segment in Figure 6.2 between the left pointing arrow and the downward pointing arrow is a superior cocaine-control policy to the current one. Those plans all offer greater accomplishment at less control cost than the current policy does.

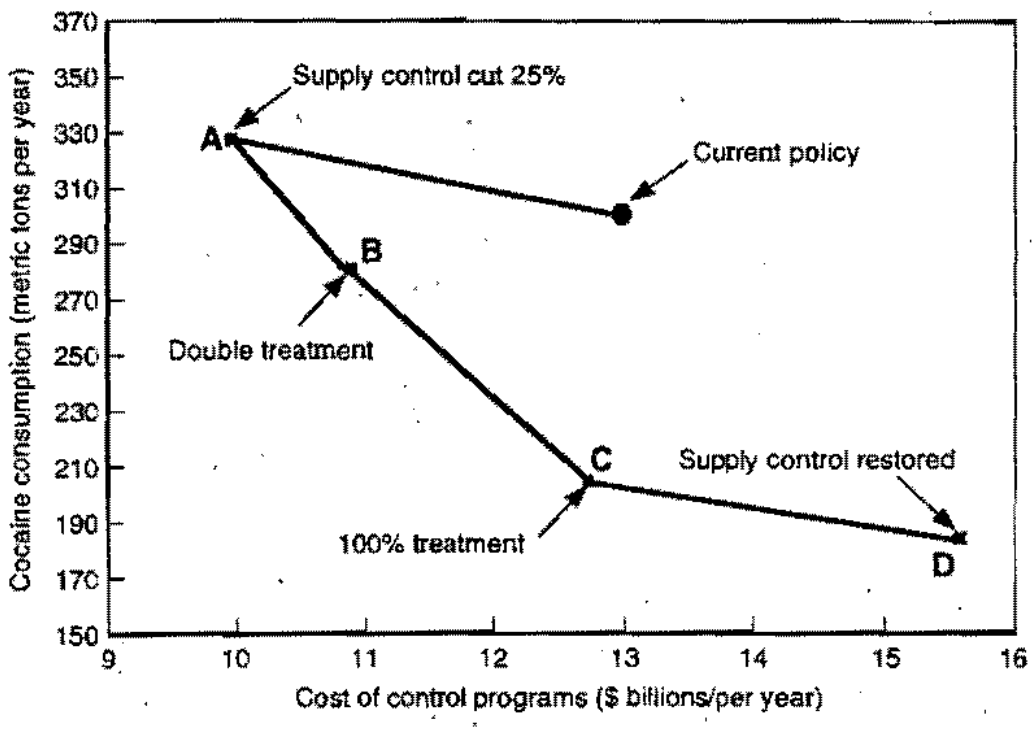

Figure 6.1—Effect of Alternative Composite Programs on Cocaine Consumption

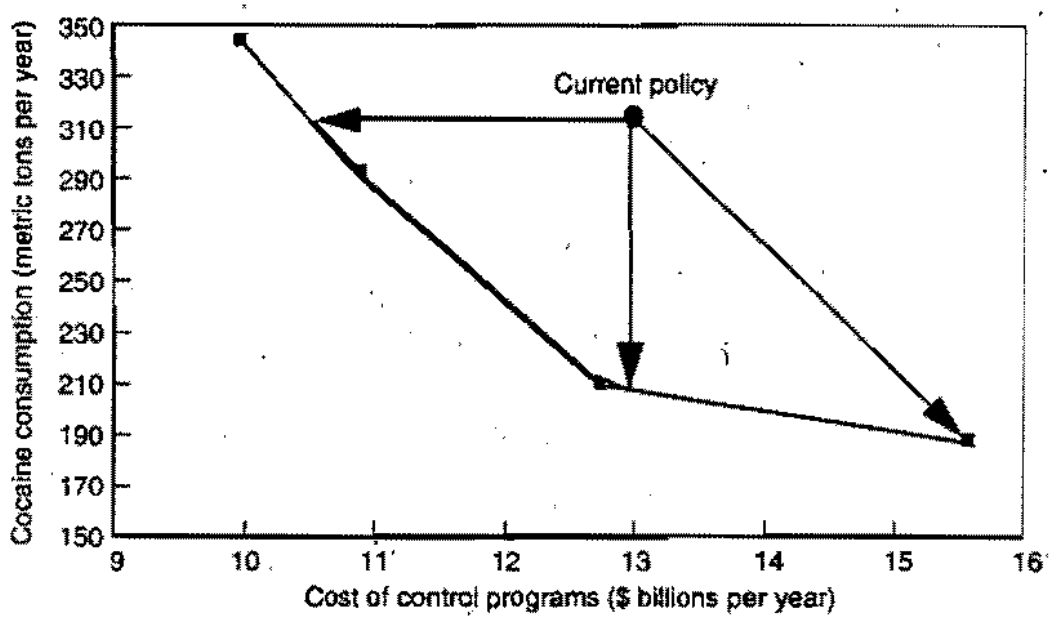

Figure 6.2—Continuous Range of Alternatives to Current Cocaine-Control Policy

The left-pointing arrow in Figure 6.2 indicates a plan that holds cocaine consumption at the level obtained under the current control policy while accomplishing a considerable reduction in the cocaine-control budget. The arrow pointing straight down identifies the plan with the same budget as the current policy but considerably greater success in decreasing cocaine consumption.

Finally, the arrow slanting to the right shows the consequences of going directly to the plan that holds the supply-control programs at current levels and offers 100 percent treatment. Such a plan costs more than the others—about one-fifth more than the current policy—but it may be the most politically feasible.

Up to now, this analysis has presented average results over 15 projection years, which have provided an overview of the cost-effectiveness of alternative composite strategies. However, by themselves they tend to create the impression that the effect of alternative plans is uniform over the projection years. On the contrary, the differences between alternatives get larger over time (see Figure 6.3).

The dashed line in Figure 6.3 shows the projected year-by-year consumption levels under the current control policy. This projection reflects the incidence (new users per year) scenario adopted for this analysis.[3] Our model does not attempt to predict cocaine consumption in the future under current policies, but rather (via the incidence scenario), it assumes a future path of consumption under current policies.

[3]See Appendix C for a discussion of the incidence scenario used throughout this analysis: Incidence is assumed to decline linearly to half its current level by 2007.

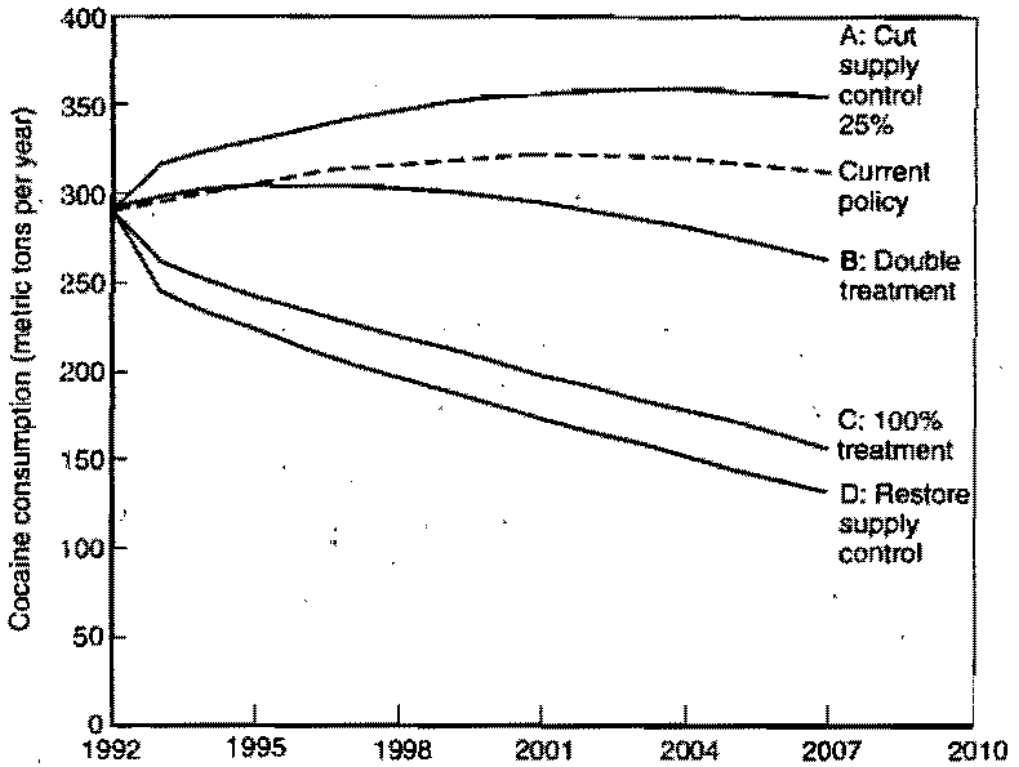

Figure 6.3—Dynamics of Changes in Cocaine Consumption

The model then predicts the quantitative impact of changes in control programs on future consumption.

The solid lines in Figure 6.3 present the year-by-year consequences of the four alternatives. The lowest line in the graph shows that expanding treatment without cutting supply control (Alternative D) can cut cocaine consumption by slightly more than half by the year 2007. The decrease would be accomplished primarily by reducing heavy-user consumption (see Figure 6.4).

To conclude this analysis, we expand our focus to include the other two evaluation criteria considered in Chapter Five—the number of cocaine users and the societal costs of cocaine use. Table 6.2 reports our estimates of the outcomes over the 15-year projection period for all three of our evaluation criteria.

Decreasing supply control by 25 percent and doubling treatment (Alternative B) would leave the number of users essentially unchanged from that under the current cocaine-control policy, while decreasing average annual consumption by 20 metric tons (a 6 percent reduction). This composite program would save $2.1 billion in annual costs of cocaine control and $3.2 billion in annual societal costs, for a total annual saving of $5.3 billion.

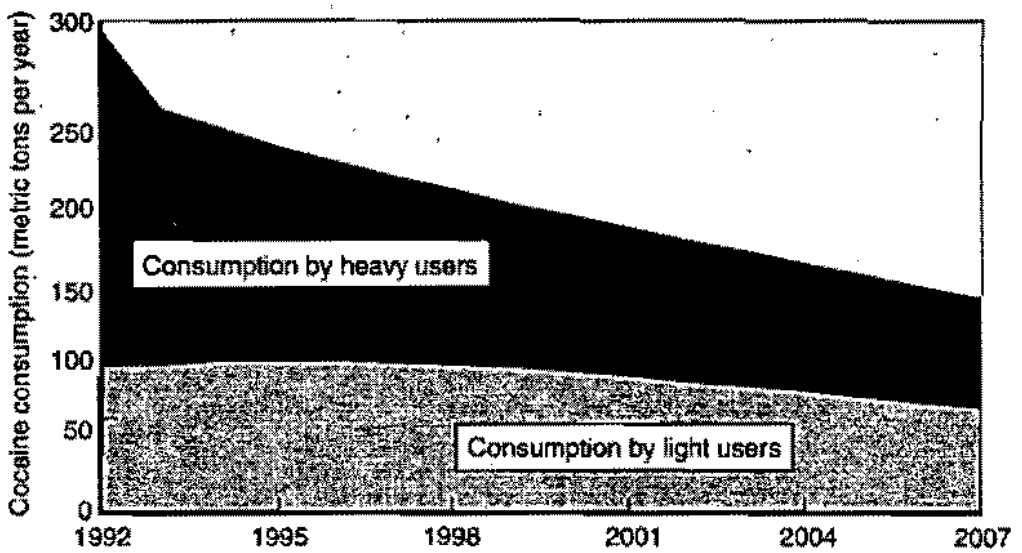

Figure 6.4—Dynamics of Consumption Change Under Alternative D (100 Percent Treatment, No Cut in Supply-Control Budget)

Table 6.2

Results of Alternative Composite Plans

Item	Current Policy	Composite Plan: 25% Cut Supply Control (A)	Double Treatment (B)	100% Treatment (C)	Restore Supply Control (D)
Cocaine Users at Year End (millions)					
Light users	5.16	5.31	5.39	5.48	5.29
Heavy users	1.90	1.97	1.67	1.19	1.13
All users	7.06	7.28	7.06	6.67	6.42
Cocaine Consumption (metric tons per year)					
Light users	86	94	95	94	85
Heavy users	228	250	199	117	103
All users	314	344	294	211	188
Price of Cocaine and User Expenditure on Cocaine					
Price ($/gram)	126	101	104	115	151
Expenditure ($ billions/year)	39.5	34.6	30.7	24.3	28.4
Societal Costs of Cocaine ($ billions per year)					
Crime	7.7	6.7	6.0	4.7	5.6
Lost productivity	21.3	23.3	19.8	14.3	12.7
Total	29.0	30.0	25.8	19.0	18.3
Total Cost of Cocaine ($ billions per year)					
Control cost	13.0	10.0	10.9	12.7	15.6
Societal cost	29.0	30.0	25.8	19.0	18.3
Total	42.0	40.0	36.7	31.7	33.9

NOTE: Alternative A cuts all three supply-control program budgets by 25 percent; alternative B spends a third of the supply-control savings on doubling the current treatment budget; alternative C spends nearly all the supply control savings to treat 100 percent of heavy users each year; and alternative D treats 100 percent of heavy users each year with no cut in the supply-control budget. Estimates are annualized values over 15 projection years using a 4 percent real discount rate. All dollar values are expressed in 1992 dollars.

Further expanding treatment to cover all heavy users (Alternative C) would decrease the number of users by 0.39 million and decrease average annual consumption by 103 metric tons, relative to current policy. The total annual cost of cocaine control would be only $0.3 billion less than under current policy, but societal costs would decrease by $10.0 billion, for a total annual saving of $10.3 billion compared to current policy.

Finally, Alternative D's restoration of the supply-control budget (treating all heavy users without changing the current levels of supply-control programs) would decrease user counts, annual consumption, and societal costs even more. However, restoring the supply-control budget increases control costs more than it decreases societal costs, so the total annual saving relative to current policy, $8.1 billion, is smaller than that under Alternative C.

Cuts in supply control make price decrease enough when changing from current policy to Alternative A for user expenditure to also decrease. The increase in price when moving to Alternatives B and C results from supply-control efforts being spread over smaller amounts of cocaine traffic (as treatment increases, cocaine consumption goes down, so a given amount of supply control is more effective per unit of supply and affects price more). But here the price effect is very small, so expenditure moves in the same direction as consumption.

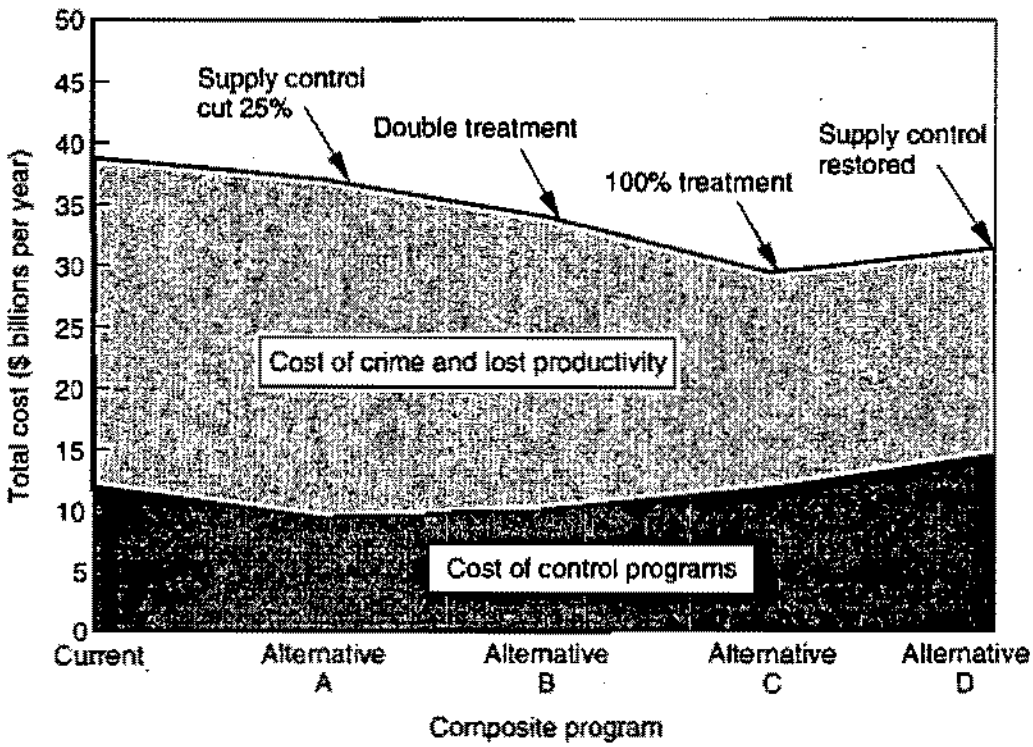

Figure 6.5—Effect of Composite Cocaine-Control Programs on Total Societal Cost

The alternative plans affect our three evaluation criteria similarly: The number of users, consumption, and societal cost all increase when supply-control budgets are cut (Alternative A), they all decrease when treatment is expanded (Alternatives B and C), and they decrease some more when the supply-control budgets are restored (Alternative D).

However, the total cost to society (the sum of control cost and societal cost) has a different pattern (see the bottom row of Table 6.2 and Figure 6.5). The total cost of cocaine to society decreases when supply-control budgets are cut, decreases some more when treatment is expanded, and then increases when the supply-control budgets are restored. The decrease in the first step and the increase in the final step both occur because supply control adds more to control costs than it subtracts from societal costs.

COCAINE SUPPLY

This appendix presents an overview of the cocaine production process. It constructs both a physical account (metric tons of cocaine produced) and a financial account (cost of producing the cocaine) in order to explain the factors affecting output price (total cost divided by net product). The appendix concludes with estimates of the physical and financial accounts for 1992.

STAGES OF PRODUCTION

We divide cocaine production into six stages, each described by its output:

- Leaf
- Coca paste
- Cocaine base
- Cocaine in the source country
- Wholesale cocaine in the United States
- Retail cocaine in the United States

The first four stages accomplish the chemical processing of the original agricultural product into cocaine; the last two distribute the cocaine from the source country to the United States, and then within the United States. This appendix and the next describe all six of these stages. Elsewhere in this report, the first four stages are treated as a single stage, production of cocaine in the source countries.

PHYSICAL ACCOUNT

At each production stage the output from the previous stage becomes the input to the current stage. That input is then transformed by a yield factor into the gross product of the current stage:

$$G = qN(i-1) \tag{A.1}$$

$N(i-1)$ = net-product output from previous production stage, input to current production stage, i

q = yield factor (ratio of metric tons of gross product to metric tons of input from previous production stage)

G = gross product at this production stage

This gross product, however, does not constitute the output of the current stage. Some of the product gets consumed in this stage's form, and some is lost through seizures by supply-control programs. Consequently, the net product available to become the input to the following production stage is gross product less consumption less seizures:

$$N(i) = G - C - X \tag{A.2}$$

C = consumption of this stage's product

X = seizure of product by supply-control programs

$N(i)$ = net product of production stage i

FINANCIAL ACCOUNT

Total Cost

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 (the first term in Eq. (A.3)), plus the processing cost of converting that input to gross output, including all capital, labor, and material costs (the second term of Eq. (A.3)), plus the cost to producers of supply-control financial sanctions[1] (the third term of Eq. (A.3)), minus the offsetting revenue from consumption of this stage's product[2] (the fourth term of Eq. (A.3)):

$$T = P(i-1)N(i-1) + K(X)G + S(X) - \left[\frac{P(i-1)}{q} + K(X)\right]C \tag{A.3}$$

$P(i-1)$ = price of input (price of net product from stage $i-1$)

K = processing cost per unit of gross product

S = financial sanctions

T = total producer cost of this production stage

Note that the level of financial sanctions, S, is specified in Eq. (A.3) as being a function of the level of cocaine seizures, X. In fact, as Appendix B elaborates, we assume

[1]The financial sanctions include asset seizures, the cost to producers of drug dealer and agent arrests, and the costs to producers of drug dealer and agent imprisonment.

[2]The price of the product sold for consumption is assumed to just cover the cost of production (purchase of input from previous production stage plus processing cost).

that as cocaine seizures increase, each component of financial sanctions (asset seizures and arrest and imprisonment of drug dealers and their agents) increases proportionately. This "fixed factor" specification of the direct effects of supply control is an approximation to a more complex model that would include varying proportions. For example, the interdiction model of Caulkins, Crawford, and Reuter (1993) has cocaine seizures and financial sanctions varying in different proportions as drug smugglers adapt their strategy to the level of supply control.

The processing cost factor, K, is also specified in Eq. (A.3) as a function (nonlinear in this case) of the level of cocaine seizures, X. Again, Appendix B provides the details. In summary, as cocaine seizures and financial sanctions increase, cocaine suppliers seek ways to limit those damages. The revised supply strategies add to processing costs, in return for holding the seizure and sanction losses below what they otherwise would have been.

Price of Net 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:

$$P(i) = \frac{T}{N(i)} \tag{A.4}$$

As Appendix B describes in detail, this analysis considers the amount of product seized, X, the financial sanctions, S, and the processing cost per unit output, K, to all be increasing functions of the supply-control budget, B, for the given production stage, i. Product seized, X, is also an increasing function of gross production, G, for the given production stage. Using B to indicate that functional dependence and expressing inputs and gross product in terms of net product (by solving Eqs. (A.1) and (A.2) to get $G = N(i) + C + X$ and $N(i-1) = [N(i) + C + X]/q$) reveals the overall dependence of output price on the supply-control budget:

$$P(i) = \frac{\left[\frac{P(i-1)}{q} + K(B_i)\right]\left[N(i) + C + X(B_i, G_i)\right] + S(B_i)}{N(i)} \tag{A.5}$$

This equation shows that the output price from a given production stage is unambiguously an increasing function of the supply-control budget at that stage.

Dividing each term of the numerator in Eq. (A.5) by the net product, $N(i)$, shows that the price, $P(i)$, equals a first term that does not vary with the net product plus a second term that decreases as the net product increases (provided the effect on X of gross production, G, is not too large, which is the case with the parameter estimates used in this analysis). Thus, holding the supply-control budget constant, an increase in the net product causes the price of that product to decrease. In other words, the cocaine supply curve slopes downward:

$$P(i) = \left[\frac{P(i-1)}{q} + K(B_i)\right] + \frac{\left[\frac{P(i-1)}{q} + K(B_i)\right]\left[C + X(B_i, G_i)\right] + S(B_i)}{N(i)} \qquad \text{(A.6)}$$

This phenomenon of the downward sloping supply curve for cocaine is discussed in Appendix E, the key point being that this is an industry supply curve (which can have a downward slope in competitive markets) rather than an individual firm supply curve (which cannot have a downward slope in competitive markets).[3] Increasing the net product in the second term of Eq. (A.6) amounts to spreading the supply-control costs to the producer over a larger volume of business, so the effect on price is diluted.

PARAMETER ESTIMATES

The empirical estimates presented here are for 1992, the base or reference year for this report's analyses. It is the year from which all our policy analysis starts, with policy changes affecting projections for years 1993 onward. Some of the information, however, comes from earlier years. Where possible and appropriate, related trends are used to update the earlier-year information to 1992. In particular, all prices and dollar values have been adjusted into 1992 dollars, using the CPI. No updating was done in the estimates of production yield factors (metric tons of cocaine per metric ton of cocaine base, for example). Those factors were obtained from 1988–1990 cocaine production accounts in ONDCP (1991b). The level of cocaine production has been fairly constant over the past few years (Holmes, 1993), so using prior years' data to estimate supply characteristics in 1992 is not unreasonable.

The supply accounts begin with coca leaf production in Bolivia, Colombia, and Peru (Table A.1). Up-to-date 1992 information was obtained from the *International Narcotics Control Strategy Report* (Bureau of International Narcotics Matters, 1993).

Table A.1

Source-Country Coca Leaf Production: 1992

Country	Area Cultivated (hectares)	Area Eradicated (hectares)	Area Harvested (hectares)	Coca Leaf Harvested (metric tons)	Coca Leaf Consumed (metric tons)
Bolivia	50,649	5,149	45,500	80,300	10,000
Colombia	38,059	959	37,100	29,600	0
Peru	129,100	0	129,100	223,900	10,000
Total	217,808	6,108	211,700	333,800	20,000

SOURCE: Bureau of International Narcotics Matters (1993).

[3]See also the extensive discussion in Caulkins (1990, pp. 287–293).

The physical accounts for the six production stages (Tables A.2 through A.5 and A.7 through A.8) trace this coca leaf through to the United States retail market by multiplying by yield factors and subtracting consumption and seizures at each stage. The product-seizures estimates are from Appendix B.

The financial accounts in these tables add processing costs and financial sanctions to input costs to get total cost. After any revenue from consumption at the given stage is subtracted, we have the total cost of the net product transferred to the next production stage.

These initial four stages in the production process are analyzed as a single, composite srage in this analysis. Accordingly, Table A.6 consolidates Tables A.2 through A.5.

RETAIL PRICE TRENDS

The real price of a gram of pure cocaine in the U.S. retail market has decreased by a factor of 6 during the past 16 years, from an estimated $756 in 1977 to $129 in 1992 (see Table A.9). This dramatic behavior becomes apparent, however, only after the observed prices have been adjusted for varying degrees of purity over time, and for background price inflation in the economy.

Table A.2

Production of Coca Leaf: 1992

Item	Amount
Physical Account	
Area cultivated, hectares	217,808
Area eradicated, hectares	6,108
Area harvested, hectares	211,700
Yield factor, metric tons leaf/hectare	1.5768
Gross product, metric tons of leaf	333,800
Consumption, metric tons of leaf	20,000
Seizure, metric tons of leaf	239
Net product, metric tons of leaf	313,561
Financial Account	
Production cost per unit, $ millions per metric ton of gross product	.00230
Production cost, $ millions	768
Revenue from consumption, $ millions	46
Financial sanction, $ millions	0
Total cost of net product, $ millions	722
Price of net product, $ millions per metric tons of leaf	0.0023

SOURCES: ONDCP (1991b), ONDCP (1992b), Bureau of International Narcotics Matters (1993), and Kennedy, Reuter, and Riley (1994). All dollar amounts in 1992 dollars.

NOTE: Consumption estimate and yield factor from Table A.1. Coca leaf seizure from Table B.1. Price of net product from Kennedy, Reuter, and Riley (1994). Production cost estimated as total cost of net product plus revenue from consumption.

Table A.3

Conversion of Coca Leaf to Coca Paste: 1992

Item	Amount
Physical Account	
Input from previous stage, metric tons of leaf	313,561
Yield factor, metric tons of paste per metric tons of leaf	0.0082
Gross product, metric tons of paste	2,573
Seizure, metric tons of paste	1
Net product, metric tons of paste	2,572
Financial Account	
Cost of input, $ millions	722
Processing cost per unit, $ millions per metric tons of gross product	0.1691
Processing cost, $ millions	435
Financial sanction, $ millions	0
Total cost of net product, $ millions	1,157
Price of net product, $ millions per metric tons of paste	0.45

SOURCES: ONDCP (1991b, 1992b), Bureau of International Narcotics Matters (1993), and Kennedy, Reuter, and Riley (1994). All dollar amounts in 1992 dollars.

NOTE: Yield factor from 1988–1990 production accounts in ONDCP (1991b, pp. 30–32). Paste seizure from Table B.1. Price of net product from Kennedy, Reuter, and Riley (1994). Processing cost estimated as a residual: total cost of net product less cost of input and financial sanction.

Table A.4

Conversion of Coca Paste to Cocaine Base: 1992

Item	Amount
Physical Account	
Input from previous stage, metric tons of paste	2572
Yield factor, metric tons of base per metric ton of paste	0.3622
Gross product, metric tons of base	932
Seizure, metric tons of base	21
Net product, metric tons of base	911
Financial Account	
Cost of input, $ million	1157
Processing cost per unit, $ millions per metric ton of gross product	0.6351
Processing cost, $ million	592
Financial sanction, $ million	0
Total cost of net product, $ million	1749
Price of net product, $ millions per metric ton of base	1.92

SOURCES: ONDCP (1991b, 1992b), Bureau of International Narcotics Matters (1993), and Kennedy, Reuter, and Riley (1994). All dollar amounts in 1992 dollars.

NOTE: Yield factor from 1988–1990 production accounts in ONDCP (1991b, pp. 30–32). Base seizure from Table B.1. Price of net product from Kennedy, Reuter, and Riley (1994). Processing cost estimated as a residual: total cost of net product less cost of input and financial sanction.

Table A.5

Conversion of Cocaine Base to Cocaine Wholesale in Source Country: 1992

Item	Amount
Physical Account	
Input from previous stage, metric tons of base	911
Yield factor, metric tons of cocaine per metric ton of base	0.9364
Gross product, metric tons of cocaine	853
Consumption,[a] metric tons of cocaine	213
Seizure, metric tons of cocaine	103
Net product, metric tons of cocaine	537
Financial Account	
Cost of input, $ millions	1,749
Processing cost per unit, $ millions per metric ton of gross product	1.373
Processing cost, $ millions	1171
Revenue from consumption, $ millions	659
Financial sanction, $ millions	107
Total cost of net product, $ millions	2,368
Price of net product, $ millions per metric ton of cocaine	4.41

SOURCES: ONDCP (1991b, 1992b), Bureau of International Narcotics Matters (1993), and Kennedy, Reuter, and Riley (1994). All dollar amounts in 1992 dollars.

NOTE: Yield factor from 1988–1990 production accounts in ONDCP (1991b, pp. 30–32). Cocaine seizure from Table B.1. Financial sanction from Table B.10. Price of net product from Kennedy, Reuter, and Riley (1994). Processing cost estimated as a residual: total cost of net product plus revenue from consumption less cost of input and financial sanction.

[a]Includes consumption in source countries and consumption in non-U.S. destination markets such as Europe, estimated as 25 percent of gross production in source countries (see ONDCP, 1991b, p. 36–37).

Table A.6

Summary of Source-Country Production of Cocaine for the United States Market: 1992

Item	Amount
Physical account	
Gross product, metric tons of cocaine	654
Seizure,[a] metric tons of cocaine	117
Net product, metric tons of cocaine	537
Financial account	
Input cost per unit, $ millions per metric ton of product	2.050
Processing cost per unit, $ millions per metric ton of product	1.407
Processing cost, $ millions	920
Financial sanction, $ millions	107
Total cost of net product, $ millions	2,368
Price of net product, $ millions per metric ton of cocaine	4.41

SOURCES: ONDCP (1991b, 1992b), Bureau of International Narcotics Matters (1993), and Kennedy, Reuter, and Riley (1994). All dollar amounts in 1992 dollars.

NOTE: Yield factor from 1988–1990 production accounts in ONDCP (1991b, pp. 30–32). Cocaine seizure from Table B.5. Financial sanction from Table B.10. Price of net product from Kennedy, Reuter, and Riley (1994). Processing cost estimated as a residual: total cost of net product less cost of input and financial sanction.

[a]Includes seizures from previous stages transformed into cocaine equivalents (seizures at each stage multiplied by the product price at that stage, summed, and then divided by the source-country price of cocaine).

Table A.7

Transportation of Cocaine to the United States: 1992

Item	Amount
Physical Account	
Input from previous stage, metric tons of cocaine	537
Yield factor, metric tons of cocaine per metric ton of cocaine	1.0
Gross product, metric tons of cocaine	537
Seizure, metric tons of cocaine	94
Net product, metric tons of cocaine	443
Financial Account	
Cost of input, $ millions	2,368
Processing cost per unit, $ millions per metric ton of gross product	8.853
Processing cost, $ millions	4,754
Financial sanction, $ millions	409
Total cost of net product, $ millions	7,531
Price of net product, $ millions per metric ton of cocaine	17.00

SOURCES: ONDCP (1992b), and Kennedy, Reuter, and Riley (1994). All dollar amounts expressed in 1992 dollars.

NOTE: Cocaine seizure from Table B.5. Financial sanction from Table B.10. Price of net product from Kennedy, Reuter, and Riley (1994). Processing cost estimated as a residual: total cost of net product less cost of input and financial sanction.

Table A.8

Retailing Cocaine in the United States: 1992

Item	Amount
Physical Account	
Input from previous stage, metric tons of cocaine	443
Yield factor, metric tons of cocaine per metric ton of cocaine	1.0
Gross product, metric tons of cocaine	443
Seizure, metric tons of cocaine	152
Net product (consumption), metric tons of cocaine	291
Financial Account	
Cost of input, $ millions	7,531
Processing cost per unit, $ millions per metric ton of gross product	51.93
Processing cost, $ millions	23,004
Financial sanction, $ millions	7,062
Total cost of net product, $ millions	37,598
Price of net product, $ millions per metric ton of cocaine	129.2

SOURCES: ONDCP (1992b), Godshaw, Koppel, and Pancoast (1987), and Kennedy, Reuter, and Riley (1994). All dollar amounts expressed in 1992 dollars.

NOTE: Cocaine seizure from Table B.5. Financial sanction from Table B.10. Price of net product from Table A.9 below. Processing cost estimated as a residual: total cost of net product less cost of input and financial sanction.

Table A.9

Derivation of the Retail Price of Cocaine

Year	Price per Gram	Percent Purity	Price per Pure Gram	Consumer Price Index (1983=100)	Real Price (1992 $) per Pure Gram
1977	138.8	42.5	326.7	60.6	755.8
1978	138.0	42.5	324.7	65.2	698.3
1979	153.3	45.5	337.0	72.6	650.8
1980	154.7	49.3	313.8	82.4	533.9
1981	144.8	49.0	295.6	90.9	455.9
1982	157.2	49.9	315.0	96.5	457.7
1983	152.7	53.4	285.9	100.0	400.8
1984	150.9	59.5	253.6	103.9	342.1
1985	129.4	51.8	249.8	107.6	325.5
1986	119.0	59.8	198.9	109.6	254.5
1987	119.6	75.3	158.9	113.6	196.1
1988	104.2	78.3	133.1	118.3	157.8
1989	99.8	79.9	124.8	124.0	141.2
1990	125.5	74.8	167.8	130.7	180.0
1991	112.2	80.9	138.7	136.2	142.8
1992	104.0	80.5	129.2	140.2	129.2

SOURCE: Price and purity data from the DEA's System to Retrieve Information from Drug Evidence (STRIDE). See Caulkins (1993) for the methodology used to construct the series for price per gram and price per pure gram. Adjustment to 1992 dollars based on the CPI from the January 1993 Economic Report to the President.

There are at least three plausible explanations for the decrease in the retail price of cocaine:

- Cocaine suppliers have learned how to run their business more efficiently over time, improving their techniques of avoiding law enforcement by trial-and-error experimentation.
- There are economies of scale in the cocaine supply business, and production costs have declined as the market has expanded.
- The cocaine market has expanded faster than supply-control penalties have increased, so the penalties have been spread over a larger volume of business, resulting in a decrease in the additional charge per unit of product necessary to compensate for the penalties.

All three explanations presumably contribute to the total decrease, but whether this is a complete list and what proportion each explanation contributes is not known.

The direct result of supply-control programs is to increase the price of cocaine. The indirect result (and ultimate purpose) is to reduce cocaine consumption (through current users reducing their consumption in response to the price increase and the number of future users decreasing as inflows of new users decrease and outflows of existing users increase in response to the price increase).

Supply control causes the price of cocaine to increase in three different ways. When production expands to replace seizure losses, the sales price goes up to cover the replacement cost of the seizures. Additional price increases occur to cover the costs of "financial sanctions" imposed on producers (seized assets and arrests and imprisonment of drug dealers or their agents). Finally, cocaine producers do not passively accept product seizures and financial sanctions. They actively take precautions to avoid the supply-control penalties to the extent possible. Those precautions increase the processing costs at each production stage.

PRODUCER COSTS IMPOSED BY SUPPLY-CONTROL PROGRAMS

Supply-control programs seize product, impose financial sanctions, and affect the processing cost. The first two effects are direct program influences; the third is indirect in that processing costs increase as producers adopt production strategies that reduce their exposure to the direct supply controls.

Processing Cost

Processing cost is assumed to increase as the level of supply-control activity (indexed by product seizures) increases. The following specification includes the extremes where supply control has no effect on processing cost ($h = 0$) and where processing cost is proportional to the level of supply control ($h = 1$).

$$K = K^* \left[\frac{X}{X^*} \right]^h \tag{B.1}$$

K = processing cost per unit of gross output

K^* = processing cost in reference situation

X = product seizures

X^* = product seizures in reference situation

h = elasticity of processing cost with respect to product seizures (percent increase in processing cost per 1 percent increase in product seizures)

Financial Sanctions

Forfeited assets increase producer costs, as does the increased compensation that must be paid to drug dealers to compensate them for arrests and imprisonment. Each of these components of financial sanctions is modeled as being proportional to the level of product seizures through a sequence of multipliers. For example, the cost of prison equals product seizures times arrests per metric ton seized times cell-years of imprisonment per arrest times the cost to producers per cell-year of dealer imprisonment:

$$S = AssetSanct + ArrestSanct + PrisonSanct \tag{B.2}$$

S = financial sanctions

$AssetSanct$ = cost to producers of assets seized along with product

$ArrestSanct$ = cost to producers of drug dealer arrests along with product seizures (increased wages paid to dealers to compensate them for the expected number of arrests they will incur)

$PrisonSanct$ = cost to producers of drug dealer imprisonment (increased wages paid to dealers to compensate them for the expected number of years they will spend in jail or prison)

$$AssetSanct = X(AssetSanctRate) \tag{B.3}$$

$AssetSanctRate$ = \$ millions of assets seized per metric ton of product seized

$$ArrestSanct = X(ArrestRate)(ArrestSanctRate) \tag{B.4}$$

$ArrestRate$ = arrests of drug dealers per metric ton of cocaine seized

$ArrestSanctRate$ = cost to drug producers of drug dealer arrests: \$ millions per arrest

$$PrisonSanct = X(ArrestRate)(PrisonRate)(PrisonSanctRate) \tag{B.5}$$

$PrisonRate$ = cell-years of imprisonment of drug dealers per arrest

$PrisonSanctRate$ = cost to producers of drug dealer imprisonment (\$ millions per cell-year)

PUBLIC COST OF SUPPLY-CONTROL PROGRAMS

Turning from the discussion of how supply controls achieve their aim of increasing the cost of doing business for drug producers, we now consider the other side of the coin, i.e., how much the public must pay to establish the supply controls.

Total Cost

Total public cost is the cost of seizing product (including the cost of seizing assets and the immediate cost of making drug dealer arrests which occur along with the product seizures), minus the deposits in the Assets Forfeiture Fund generated by the asset seizures, plus the court costs of processing arrests of drug dealers and the jail and prison costs of incarcerating convicted drug dealers:

$$B = \left[Z - V + A + Y\right]X \tag{B.6}$$

B = total expenditure for supply control at a given production stage

X = cocaine seizures

Z = seizure costs per metric ton of cocaine seized (includes costs of seizing assets and of arresting drug dealers; excludes costs of processing arrests through court system and costs of jail and prison time)

V = value to public of seized assets (i.e., salvage value or realized value) per metric ton of cocaine seized

A = cost of processing arrests per metric ton of cocaine seized

Y = imprisonment cost of drug dealers per metric ton of cocaine seized (the cost of the cell years resulting from the arrests that lead to convictions and sentencings)

All these costs are specified per unit of product seized in the reference case, then a diminishing productivity effect (where marginal productivity is less than average productivity[1]) is assumed to operate across all types of costs:

$$B = \left[ZX^* - VX^* + AX^* + YX^*\right]\left[\frac{X}{X^*}\right]^{(1/m)} \tag{B.7}$$

X^* = cocaine seizures in reference situation

[1]To see why m can be interpreted as the ratio of the marginal productivity of the supply-control budget in generating product seizures to the average productivity of the supply-control budget in generating product seizures, let u be the first factor in Eq. (B.8), note that u does not vary with the control budget, and then differentiate with respect to the control budget, B, to find:

$$X(B) = uB^m;\ X'(B) = muB^{m-1};\ X'(B) = m\left[\frac{X(B)}{B}\right]$$

m = diminishing-productivity parameter (ratio of marginal productivity of supply-control expenditure to the average productivity, $0 < m < 1$)

Control Level as a Function of Control Budget

In this analysis, all control activities (at a given production stage) are assumed to be driven by the amount of product seized at that stage. Therefore, knowing product seizure as a function of control budget enables us to determine all control activities as a function of the control budget. This relationship enables a single policy choice (the supply-control budget) to determine all supply-control intervention at a given production stage. Solving Eq. (B.7) for the amount seized as a function of the control budget shows that product seizures are proportional to the control budget raised to a power that is the diminishing-productivity parameter:

$$X = \left[\frac{X^*}{\left(ZX^* - VX^* + AX^* + YX^*\right)^m}\right] B^m \tag{B.8}$$

Cost of Seizing Product

The cost of seizing product at a given production stage depends in part upon the amount seized, and in part upon the proportion of gross production that is seized. Seizure costs depend on the *amount* seized when intelligence has located the cocaine so that amount seized depends only upon the law enforcement resources devoted to the targeted locations. Seizure costs depend on the *proportion* seized when seizures result from random searches. For example, if a certain number of dollars allows one to (successfully) search a certain fraction of incoming vessels or containers, then doubling the amount of cocaine coming into the United States would also double the amount of cocaine seized. However, the total cost of seizures would remain essentially unchanged because licit commerce in those vessels or containers swamps illicit commerce.

We model this cost relationship as a weighted average of the two costing principles, where $1 - p$ and p are the weights. If $p = 0$, the first principle holds exclusively, and total seizure cost, ZX, varies with the amount of cocaine seized, X. If $p = 1$, the second principle holds exclusively, and seizure cost varies with the proportion of gross production of cocaine that is seized, X/G. When $0 < p < 1$, total seizure cost varies with both the amount of cocaine and the proportion of gross cocaine production that is seized:

$$ZX = \left[1 - p\right]WX + p\left[WG^*\right]\left[\frac{X}{G}\right] \tag{B.9}$$

W = average seizure cost per unit of product seized in reference situation

p = fraction of total cost due to relative size of seizure (as opposed to absolute size)

G = gross product

G^* = gross product in reference situation

Dividing both sides of Eq. (B.9) by the amount seized, X, gives the average cost per metric ton seized as a function of the weighting factors between the two cost principles, p, and the level of gross production, G:

$$Z = W\left[(1-p) + p\left(\frac{G^*}{G}\right)\right] \tag{B.10}$$

Other Cost Factors

The remaining cost factors in Eq. (B.8) are modeled as straightforward products of multipliers. Not surprisingly, many of these multipliers are the same ones used in the calculation of the cost to producers. In fact, in general, only the last multiplier in a sequence changes:

$$V = (AssetSanctRate)(ForfeitRate) \tag{B.11}$$

ForfeitRate = proportion of asset seizures salvaged (forfeited to government, as opposed to being destroyed)

$$A = (ArrestRate)(ArrestCostRate) \tag{B.12}$$

ArrestCostRate = public cost of processing drug dealer arrests ($ millions per arrest)

$$Y = (ArrestRate)(PrisonRate)(PrisonCostRate) \tag{B.13}$$

PrisonCostRate = public cost of imprisoning drug dealers ($ millions per cell-year).

PARAMETER ESTIMATES

The parameters in our model of supply-control programs are estimated below. Almost every estimate should contain qualifiers such as "approximate," "roughly estimated as," or "assuming that 19XX behavior holds true today." However, rather than burden the exposition with repeated cautions, such qualifiers are taken as given.

This analysis reports amounts of cocaine products in metric tons[2] (1,000 kilograms or 1 million grams) and usually states dollars in millions. This convention has the following useful feature: The cost of cocaine stated as millions of dollars per metric ton in discussions of supply is numerically the same as the cost stated as dollars per gram in discussions of retail price.

Seizures and Arrests

Table B.1 presents estimates of cocaine product seizures, drug-production asset seizures, and arrests of drug dealers and their agents, accomplished through source-country controls in South and Central America during 1992. This information has been assembled in the *International Narcotics Control Strategy Report* (Bureau of International Narcotics Matters, 1993). The parallel information on interdiction and domestic enforcement is combined in Tables B.2 through B.6.

Tables B.2 and B.3 estimate arrests of drug dealers and their agents accomplished by interdiction and by domestic enforcement. Table B.4 combines the information in Tables B.1 and B.3 to determine the number of arrests for cocaine dealing by production stage.

Tables B.5 and B.6 present estimates of the amount of cocaine seized and the value of cocaine-producing assets seized during 1992.

Table B.1

Source-Country Seizures and Arrests: 1992

	Seizures (metric tons)						
Country	Leaf	Paste	Base	Cocaine	Aircraft Seized	Vehicles Seized	Arrests
Bolivia	189	0	8	1	48	64	1,226
Colombia	50	0	6	32	0	0	1,700
Equador	0	0	0	4	0	22	1,975
Peru	0	1	7	0	7	0	3,707
Venezuela	0	0	0	3	0	0	1,022
Costa Rica	0	0	0	2	0	0	525
Guatemala	0	0	0	10	10	0	0
Honduras	0	0	0	2	0	0	1,462
Mexico	0	0	0	39	0	0	27,577
Panama	0	0	0	10	0	0	657
Total	239	1	21	103	65	86	3,9851

SOURCE: Bureau of International Narcotics Matters (1993).

[2]To convert tons (2,000 pounds) into metric tons, multiply by 0.9072; to convert pounds into metric tons, divide by 1,000 and multiply by 0.4536.

Table B.2

Total Arrests for Drug Abuse Violations: United States, 1986–1991 (In thousands)

Item	1986	1987	1988	1989	1990	1991
			Arrests for Sale or Manufacture			
Heroin/cocaine	104.7	132.2	196.4	260.1	228.8	227.3
Marijuana	65.1	65.6	64.7	84.4	66.5	61.6
Other	37.1	44.1	55.4	96.7	49.0	48.5
Total	206.8	241.8	316.6	441.2	344.3	337.4
			Arrests for Possession			
Heroin/cocaine	231.6	295.3	403.2	472.5	362.8	331.3
Marijuana	296.7	313.1	326.9	314.6	260.4	226.2
Other	89.0	87.2	108.6	133.4	122.0	115.1
Total	617.3	695.6	838.7	920.5	745.2	672.7

SOURCE: Federal Bureau of Investigation (1987 through 1991, first two tables in Sec. IV, "Persons Arrested").

Table B.3

Arrests for Sale or Manufacture of Drugs: United States, 1991

Drug	Number (thousands)	Percent
Cocaine	191.8	57
Heroin	35.5	11
Marijuana	61.6	18
Other	48.5	14
Total	337.4	100

SOURCE: Table B.2, DEA (1990).

NOTE: Total arrests for heroin and cocaine allocated in proportion to DEA arrests for heroin and cocaine during 1990 (see DEA, 1990, pp. 79, 87)

Table B.4

Arrests of Cocaine Dealers and Agents: 1992

Production Stage	Arrests (thousands)
Domestic enforcement[a]	187.4
Interdiction[b]	4.4
Source country[c]	35.9

SOURCE: ONDCP (1992b, estimates for 1992), Bureau of Justice Statistics (1992), Godshaw, Koppel, and Pancoast (1987), Bureau of International Narcotics Matters (1993).

[a]The 191,800 total U.S. arrests for cocaine selling in 1991 (see Table B.3), minus the 4,400 attributed below to interdiction.

[b]The sum of 7,555 arrests by the INS (ONDCP, 1992b, p. 176), with 57 percent attributed to cocaine (assuming that arrests by this agency are distributed across drugs in the same proportions as all arrests, see Table B.3), and 150 arrests by the U.S. Coast Guard (ONDCP, 1991b, p. 161), with 75 percent attributed to cocaine.

[c]The total of 39,800 arrests in South and Central America (see Table B.1), with 90 percent attributed to cocaine.

Table B.5

Seizures of Cocaine: 1992

Production Stage	Cocaine Seizures (metric tons)
Domestic enforcement[a]	152
Interdiction[b]	94
Source-country control[c]	117

SOURCE: ONDCP (1992b, estimates for 1992), Bureau of Justice Statistics (1992), Godshaw, Koppel, and Pancoast (1987), Bureau of International Narcotics Matters (1993).

[a]The sum of 68 metric tons removed from the domestic market by DEA in 1991 (Bureau of Justice Statistics, 1992, p. 482, 149.4 thousand pounds times 0.4536 metric tons per 1,000 pounds), and 84 metric tons seized by state, county, and municipal police (Godshaw et al.,1987, p. 126, 38.7 metric tons times 2.17 to adjust from 1986 to 1992, where 2.17 is the ratio of heroin arrests to cocaine arrests in 1991, the latest available year, to those in 1986, see Table B.2).

[b]The sum of 78 metric tons seized by the U.S. Customs Service and 16 metric tons seized by the U.S. Coast Guard (ONDCP, 1992b, pp. 161, 176).

[c]Bureau of International Narcotics Matters (1993). Includes cocaine equivalent—in financial harm done to producers—of leaf, paste, and base seizures; see Tables B.1 and A.2 through A.5.

Table B.6

Seizures of Cocaine-Production Assets: 1992

Production Stage	Asset Seizures ($ millions)
Domestic enforcement[a]	$12
Interdiction[b]	254
Source-country control[c]	7

SOURCE: ONDCP (1992b, estimates for 1992), Bureau of Justice Statistics (1992), Godshaw, Koppel, and Pancoast (1987), Bureau of International Narcotics Matters (1993).

NOTE: These asset values are the losses to drug producers due to asset seizures. Only a part of these losses is realized as a gain to the public (see Table B.8).

[a]The sum of $434 million in assets seized by Organized Crime Drug Enforcement task forces, $307 million in assets seized by the Drug Enforcement Administration (all DEA asset seizures prorated by domestic enforcements share of the DEA budget), and $157 million in assets seized by the Federal Bureau of Investigation (ONDCP, 1992b, pp. 94, 99, and 121) times 57 percent attributed to cocaine (the proportion of drug dealer arrests that are for cocaine; see Table B.3).

[b]Seizures of aircraft and vessels (ONDCP, 1992b, pp. 161, 176), assumed to cost producers $100,000, and of vehicles, assumed to cost producers $15,000; 57 percent of U.S. Customs Service seizures and 75 percent of U.S. Customs seizures attributed to cocaine.

[c]Seizures of aircraft and vessels (Bureau of International Narcotics Matters, 1993), assumed to cost producers $100,000, and of vehicles, assumed to cost producers $15,000; 90 percent of seizures attributed to cocaine.

Public Cost of Supply Control

To estimate the total public cost of cocaine supply control programs requires calculating the total of federal agency budgets, state and local agency budgets, court budgets, and jail and prison budgets. Table B.7 estimates the agency expenditures, then Table B.8 adds the courts and corrections expenditures.

Table B.9 expresses agency budgets, arrests, and asset seizures as amounts per metric ton of cocaine seized, the form in which this information enters our model.

Table B.7

Agency Budgets for Cocaine Control

Agency	Drug Control Budget ($ millions)	Percent Cocaine	Cocaine Budget ($ millions)
Domestic Enforcement			
Organized Crime Drug Enforcement[a]	172	57	98
High-Intensity drug trafficking areas	86	57	49
DEA: domestic[b]	249	57	142
Federal Bureau of Investigation	205	57	117
State and local police[c]	10,202	57	5,814
Total			6,220
Interdiction			
U.S. Customs Service	785	57	447
Immigration and Naturalization Service	141	57	80
Federal Aviation Administration	23	75	17
U.S. Coast Guard	436	75	327
Department of Defense[d]	1,135	75	851
Total			1,723
Source-Country Control			
Bureau of International Narcotics Matters	145	90	131
Bureau of Politico/Military Affairs	75	90	68
DEA: International[e]	461	90	415
Agency for International Development	258	90	232
Total			845

SOURCE: Office of Management and Budget (1993, actual 1992 budgets), Godshaw, Koppel, and Pancoast (1987, p. 119).

NOTE: The proportion of domestic enforcement budgets spent on cocaine (57 percent) estimated by the proportion of all U.S. arrests for the sale and manufacture of drugs that are for cocaine (see Table B.3). Customs and Immigration are assumed to be like domestic enforcement. Other interdiction efforts are assumed to be more focused on cocaine (75 percent) and international efforts assumed to be dominated by cocaine (90 percent).

[a]OCDE budget less DEA and FBI contributions (to avoid double counting).

[b]Domestic budget for the DEA includes "domestic enforcement" and "state and local task forces."

[c]In 1986, state, county, and municipal governments spent $4,890 million on drug control (Godshaw, Koppel, and Pancoast, 1987, p. 119). Multiplying by 1.279 to adjust for price inflation from 1986 through 1992, and then multiplying by 1.631 to adjust for the growth in control activity yields the estimated $10,202 million spent on drug control in 1992. The 1.631 factor is the growth in U.S. arrests for the sale or manufacture of drugs from 1986 to 1991, the most recent year for which data are available (see Table B.2).

[d]DoD total budget for drug control, minus the "demand reduction" component.

[e]The international budget for the DEA is the total budget less the domestic portion.

Table B.8

Total Cocaine Supply-Control Expenditure: 1992
(in $ millions)

Production Stage	Agency Costs	Forfeited Assets[a]	Courts	Corrections	Total
Domestic enforcement	6,220	−202	234	3,222	9,474
Interdiction	1,723	−100	6	76	1,705
Source-country control	845	−3	15	14	871
Total	8,788	−305	255	3,312	12,050

SOURCES: Tables B.4, B.6, and B.7.

NOTE: For domestic enforcement and interdiction: Court cost to public estimated as $1,251 per arrest. During 1990 in the United States, for all levels of government, court costs were $16,549 million and total arrests were 14.195 million, making the cost per arrest $1,166, or $1,251 in 1992 dollars (Bureau of Justice Statistics, 1992, pp. 3, 432). Corrections cost to the public estimated at $23,658 per cell-year. During 1990 in the United States, for all levels of government, correction costs were $24,960 million and the average daily incarcerated population was 408,075 in jail and 774,375 in state and federal prison, making the cost per cell-year of incarceration $21,658, or $23,232 in 1992 dollars (Bureau of Justice Statistics, 1992, pp. 3, 611, 640). Cell-years per arrest estimated as 0.74 (Reuter, 1991, p. 142). In 1988, 147,000 seller arrests for cocaine dealing resulted in an estimated 108,000 cell-years of incarceration. For source countries: Court costs per arrest and corrections cost per cell-year assumed to be one-third those in the United States. Cell-years per arrest assumed to be 0.05, which is the U.S. estimate, 0.74, times 0.01, divided by 0.15, where 0.01 is an estimate of the conviction rate in source countries (Hanratty and Meditz, 1990, p. 310) and 0.15 is an estimate of the conviction rate in the United States (Rydell, 1986, p. 240).

[a]Revenue (shown as a negative cost) from the realized value to the public of seized assets is equal to asset seizures (see Table B.6) times the forfeiture rate, 0.394. The forfeiture rate is the portion of producer losses that translate into public gains. During 1992, $531 million was deposited in the Assets Forfeiture Fund (Office of Management and Budget, 1993, p. 60) from all drug-control efforts. The total of the asset seizures from all drugs given in the footnotes to Table B.6 (before prorating to cocaine) is $1,349 million. Thus, 39.4 percent of the assets seized became public revenue in 1992.

Table B.9

Annual Agency Budgets, Arrests, and Asset Seizures per Metric Ton of Cocaine Seized

Production Stage	Agency Budget per Metric Ton Cocaine Seized ($ millions)	Arrests per Metric Ton Cocaine Seized	Asset Seizures per Metric Ton Cocaine Seized ($ millions)
Domestic enforcement	40.9211	1232.9	3.3684
Interdiction	18.3297	46.8	2.7021
Source-country control	7.7991	306.8	0.0598

SOURCE: Tables B.4 through B.8.

Financial Sanctions Imposed on Producers by Supply Control

The total financial sanctions imposed on cocaine producers by supply-control programs include the losses due to asset seizures and the compensation paid to dealers and agents for the risks of arrest and imprisonment. These sanctions amounted to $7.6 billion in 1992, most of them coming from arrest and imprisonment of cocaine dealers and agents by domestic enforcement (see Table B.10).

Table B.10

Financial Sanctions Imposed on Producers of Cocaine: 1992
(in $ millions)

Production Stage	Financial Cost to Producers Due to: Asset Seizures	Arrests	Jail and Prison	Total
Domestic enforcement	512	1199	5352	7,062
Interdiction	254	28	126	409
Source-country control	7	78	23	107
Total	773	1304	5501	7,579

SOURCES: Tables B.4, B.6 and B.7.

NOTE: For domestic enforcement and interdiction: Arrest costs to producers estimated as $6,395 per arrest (Reuter and Kleiman, 1986, p. 333, adjusted to 1992 dollars). Jail and prison costs to producers estimated as $38,588 per cell-year (Kleiman, 1992, p. 140, midpoint of range of estimates, adjusted to 1992 dollars). Cell-years per arrest estimated as 0.74 (Reuter, 1991, p. 142). In 1988, 147,000 seller arrests for cocaine dealing resulted in an estimated 108,000 cell-years of incarceration. For source countries, court costs per arrest and corrections cost per cell-year assumed to be one-third that in the United States. Cell-years per arrest assumed to be 0.05, which is the U.S. estimate, 0.74, times 0.01, divided by 0.15, where 0.01 is an estimate of the conviction rate in source countries (Hanratty and Meditz, 1990, p. 310) and 0.15 is an estimate of the conviction rate in the United States (Rydell, 1986, p. 240).

Nonlinearity Parameters

Three parameters govern the degree of nonlinearity in the producer and public costs of supply control as the level of supply control and the size of the cocaine epidemic change:

h = elasticity of processing cost with respect to product seizures (percent increase in processing cost per 1 percent increase in product seizures; see Eq. (B.1))

m = diminishing productivity parameter (ratio of marginal productivity of supply-control expenditure to the average productivity; see Eqs. (B.7) and (B.8))

p = proportion of cost due to relative size of seizure (as opposed to absolute size; see Eqs. (B.9) and (B.10))

For this analysis we adopt the following estimates: $h = 0.44$, $m = 0.8$, $p = 0.5$. The estimates of m and p are rough appreciations of discussions and general reading about the cocaine supply process. The estimate of h comes from the SOAR "Simulation of Adaptive Response" model (Crawford and Reuter, 1988), which was used to explore the increase in processing cost as producers seek to avoid increasing supply-control penalties—exactly what h measures. The SOAR model indicated that cocaine-smuggler costs increased an average of 0.44 percent per 1 percent increase in cocaine seizures (Crawford and Reuter, 1988, Table 3, p. 57).[3]

[3]An example of a calculation from the referenced Table 3 is a 3.6 percent increased smuggler cost for an 8.0 percent increase in cocaine interdicted (35.1/32.5=1.080), making $h = 3.6/8.0 = 0.45$. Averaging over all runs reported in the table results in $h = 0.44$.

This analysis uses a model of cocaine demand that divides users into two groups: heavy users who use cocaine at least weekly and light users who use cocaine at least once a year, but less than weekly. The two groups are only an approximate representation of a continuous distribution of intensity of use, but the two-group distinction is sufficient to capture the essential dynamic of cocaine demand: New users start as light users, and many quit without ever progressing to heavy use. The small proportion of light users who do become heavy users accumulates over time to about one-fifth of all users; because of their higher consumption rate, however, they account for about two-thirds of all consumption.

THEORY OF COCAINE DEMAND

Dynamic Model of Demand

The model that makes these demand dynamics explicit is Markovian, with flow rates out of the various states, except that the inflow of new users to light use (incidence) is scripted:

$$L(y) = L(y-1) + I(y) - aL(y-1) - bL(y-1) + fH(y-1) \tag{C.1}$$

$$H(y) = H(y-1) + bL(y-1) - fH(y-1) - gH(y-1) \tag{C.2}$$

L = number of light users of cocaine

H = number of heavy users of cocaine

y = calendar year

I = annual incidence of new users (changes each year according to the incidence script)

a = annual rate at which light users quit (fraction of light users at the start of a year that quit during the year)

b = annual rate at which light users progress to heavy use (fraction of light users at the start of a year who become heavy users during the year)

f = annual rate at which heavy users regress to light use (fraction of heavy users at the start of a year who become light users during the year)

g = annual rate at which heavy users quit (fraction of heavy users at the start of a year who quit during the year)

Total consumption is the sum of consumption by light users and consumption by heavy users:

$$C = C_l L + C_h H \tag{C.3}$$

C = total consumption of cocaine in the United States during the year

C_l = annual consumption of cocaine per light user

C_h = annual consumption of cocaine per heavy user

How Control Policy Affects Consumption Rates

The light-user consumption rate decreases as drug dealers (some proportion of which are also users) are incapacitated[1] in jail or prison, and it also decreases if supply controls cause the retail price of cocaine to increase.[2] The incapacitation effect of putting drug dealers in prison is a demand-side effect of supply-side programs.

The elasticity of the current consumption rate with respect to price is one-half the (total) price elasticity of demand. See the discussion at the end of this appendix, where, based on evidence from cigarette studies, it is estimated that one-half of the long-run, total response of demand to price occurs through changes in current consumption rates, while the other half occurs through changes over time in the number of users:

$$C_l = C_l^* \left[\frac{1-j}{1-j^*}\right]\left[\frac{P}{P^*}\right]^{e/2} \tag{C.4}$$

C_l^* = annual consumption of cocaine per light user in the reference year (and, in particular, at the reference year's price of cocaine)

j = incapacitation rate of light users due to imprisonment of drug dealers (drug dealers in jail or prison who were light users before they entered jail or prison as a proportion of all light users)

j^* = incapacitation rate of light users in the reference situation

P = retail price of cocaine

P^* = retail price of cocaine in the reference year

e = elasticity of demand with respect to price (percentage change in demand for cocaine per 1 percent increase in the retail price of cocaine)

[1]This analysis assumes that drug users are unable to obtain drugs while in jail or prison, but that imprisonment has no effect beyond temporary suppression of drug use. That is, the analysis assumes that being in jail or prison does not change the dynamic behavior of the drug-using population.

[2]The price elasticity, e, is a negative number (specifically, an estimated −0.5), so an increase in price, P, causes the function to decrease.

The heavy-user consumption rate responds to the incapacitation rate and the retail price just as the light-user consumption rate does; but in addition, the heavy-user consumption rate decreases with increases in the proportion of heavy users offered drug treatment (because most users stop drug use while in treatment):

$$C_h = C_h^* \left[\frac{1 - n - dt}{1 - n^* - dt^*} \right] \left[\frac{P}{P^*} \right]^{e/2} \tag{C.5}$$

C_h^* = annual consumption of cocaine per heavy user in the reference year (and, in particular, at the reference year's price of cocaine)

n = incapacitation rate of heavy users due to imprisonment of drug dealers (drug dealers in jail or prison who were heavy users before they entered jail or prison as a proportion of all heavy users)

n^* = incapacitation rate of heavy users in the reference situation

d = desistance rate (person-years that a user stops using cocaine while in a treatment program, equal to the average treatment duration times the proportion of time in treatment that people are off drugs)

t = proportion of heavy users treated during the year

t^* = proportion of heavy users treated during the year in the reference situation

How Control Policy Affects User Flows

The base-case incidence flows are a scripted scenario. However, that script is modified if supply-control programs change the retail price of cocaine. The elasticity of incidence with respect to price is one-fourth the long-run price elasticity of demand. The long-run elasticity is divided by two to separate the effect into an immediate effect on consumption rates and a gradual effect on the number of users via alterations of user flows. Then it is divided by two again to allow half of the user effect to occur through changed inflows and half to occur through changed outflows.[3]

$$I(y) = I^*(y) \left[\frac{P}{P^*} \right]^{e/4} \tag{C.6}$$

I^* = annual incidence in year y if price were equal to the reference year's price of cocaine (this is how the incidence scenario is specified)

The flow rates out of cocaine use and between light and heavy cocaine use respond to price changes similarly to incidence, except that outflows and the flow from heavy to light use are affected in the opposite direction. As price increases, more light users

[3]Using $e/2$ as the consumption elasticity and $e/4$ as the flow elasticity is only an approximation to the exact elasticities needed to divide the total long-run price elasticity of demand into half consumption and half user effects, but it turns out to be a very good approximation, so we use it instead of harder-to-motivate exact estimates. Note that e is a negative number, so that incidence decreases as retail price rises.

quit using cocaine, more heavy users quit using cocaine, and more heavy users regress to light use.[4] Price affects the flow of light users progressing to heavy use inversely, in parallel to the effect on incidence, because the progression flow is really just another type of incidence (additional heavy users rather than additional light users):

$$a = a^* \left[\frac{P}{P^*} \right]^{-e/4} \tag{C.7}$$

a^* = annual rate at which light users quit in the reference year (in particular, at the reference year's price of cocaine)

$$b = b^* \left[\frac{P}{P^*} \right]^{e/4} \tag{C.8}$$

b^* = annual rate of light-user progression to heavy use in the reference year (in particular, at the reference year's price of cocaine)

In addition to being affected by price, the flow rates out of heavy use increase as the proportion of heavy users treated, t, increases. The particular functional form in Eqs. (C.9) and (C.10) results from the assumption that the two outflows from heavy use (quits and returns to light use) increase in the same proportion as treatment expands:

$$f = f^* \left[1 + k(t - t^*) \right] \left[\frac{P}{P^*} \right]^{-e/4} \tag{C.9}$$

f^* = annual rate at which heavy users regress to light use in the reference situation

k = ratio of extra outflow rate caused by treatment to the reference situation outflow rate from heavy use

$$g = g^* \left[1 + k(t - t^*) \right] \left[\frac{P}{P^*} \right]^{-e/4} \tag{C.10}$$

g^* = annual rate at which heavy users quit in the reference situation

EMPIRICAL ESTIMATES OF COCAINE DEMAND

The following discussion establishes user counts and consumption rates in the reference year (1992), flow rates for a Markovian model of the dynamics of demand, an

[4]The price elasticity, e, is a negative number, so with a minus value it is a positive number, and increases in price cause the function to increase.

incidence scenario for 15 projection years, and an estimate of the price elasticity of demand.

User Counts and Consumption Rates

The estimates of cocaine demand in Table C.1 are notionally for 1992, even though (as with the production estimates for 1992) they are calculated from the prior year's information. Moreover, the prior year's information is by no means perfect. That said, these estimates are internally consistent and provide a reference situation for this analysis.

These demand estimates are constructed in Everingham and Rydell (1994) using the following procedure: Historical counts of users in households, users who are homeless, and users in jail or prison are assembled from separate data sources. Users in jail or prison are assumed to be (temporarily) unable to consume cocaine. The remaining users are estimated to consume cocaine at a rate that is 8 times greater for heavy users than for light users.[5] Finally, the estimated consumption rates per per-

Table C.1

Cocaine Consumption by Type of User: 1992

Location	Light Users	Heavy Users	All Users
Cocaine Users at Start of Year (millions)			
Households	5.042	1.226	6.268
Homeless	0.208	0.208	0.416
Jail/Prison	0.246	0.254	0.500
Total	5.496	1.688	7.184
Cocaine Users at End of Year (millions)			
Households	5.093	1.203	6.296
Homeless	0.257	0.262	0.519
Jail/Prison	0.246	0.254	0.500
Total	5.596	1.719	7.315
Cocaine Consumption (metric tons per year)			
Households	86.7	171.6	258.3
Homeless	3.6	29.1	32.7
Jail/Prison	0.0	0.0	0.0
Total	90.3	200.7	291.0
Consumption per Person at Start of Year (grams per person-year)			
Households	17.2	140.0	41.2
Homeless	17.2	140.0	78.6
Jail/Prison	0.0	0.0	0.0
Total	16.4	118.9	40.5

SOURCE: Everingham and Rydell(1994).

[5]In other words, nonincarcerated heavy cocaine users consume 8 times as much cocaine per year as nonincarcerated light cocaine users. Because of the differential incarceration rates, the overall average consumption rate of heavy users is only 7 times that of light users.

son are scaled to make the estimated total consumption equal the 291 metric tons total retail sales in Table A.6.

Dynamic Model of Demand

The flows and flow rates for the Markovian model of cocaine demand (in Table C.2) show that the annual number of light users who quit is only 17 percent less than the inflow of new users (0.828 million versus 0.990 million during 1992).

In other words, most cocaine users stop at the experimental stage. Only a relatively small number progress to heavy use (0.132 million in 1992). However, the total outflow rate from heavy use is only an estimated 6 percent per year (4 percent of heavy users regress to light use and 2 percent quit each year), so a heavy user once established tends to last for a long period of time.[6]

These flow rates were computed from historical evidence, using a method that did not consider historical changes in cocaine-control interventions. A useful future refinement would be to augment this demand-estimation method with the models of cocaine-control intervention constructed in this report.

INCIDENCE SCENARIO

This analysis uses an incidence scenario where the inflow of new cocaine users declines linearly (0.0329 million fewer each succeeding year) over the 15 projection years. As the heavy line in Figure C.1 shows, this scenario has incidence declining from an estimated 0.988 million new users during 1992 to half that level during 2007.

Table C.2

Dynamics of Cocaine Demand

Item	Estimate
Flow During 1992 (millions)	
Incidence of new users	0.988
Light-user quits	0.824
Progression of light users to heavy use	0.132
Regression of heavy users to light use	0.068
Heavy-user quits	0.034
Annual Flow Rates	
Light-user quit rate (a^*)	0.150
Light-user progression rate to heavy use (b^*)	0.024
Heavy-user regression rate to light use (f^*)	0.040
Heavy-user quit rate (g^*)	0.020

SOURCE: Everingham and Rydell (1994).

[6]Compounding a persistence probability of 0.96 shows that the "half life" of a heavy cocaine user is 17 years—that is, after 17 years, half of an entering cohort of heavy users will have left heavy use.

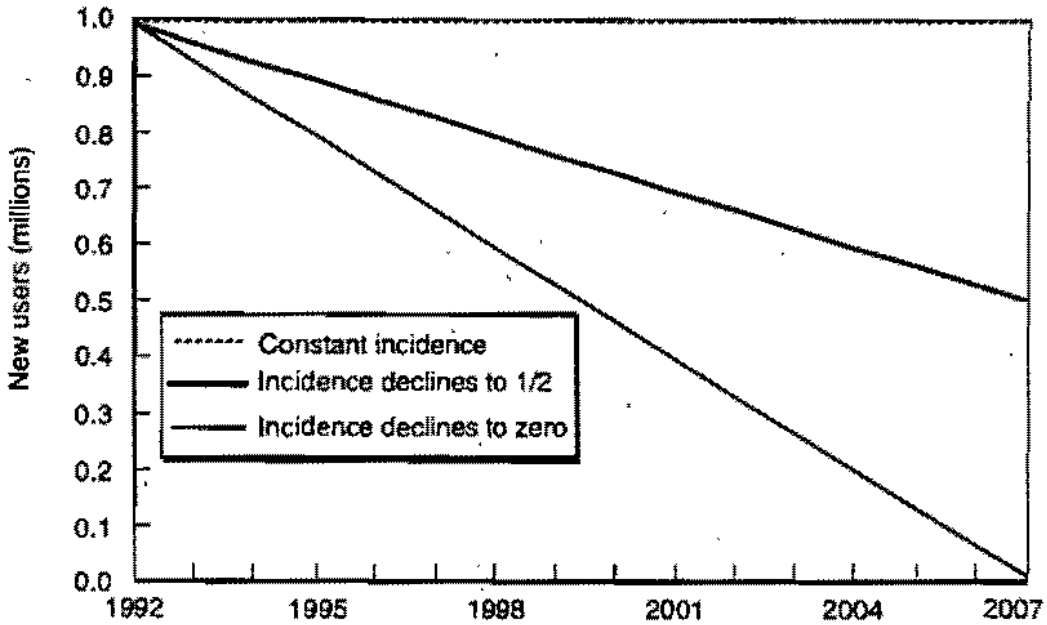

Figure C.1—Incidence Scenarios

We emphasize that this scenario is not a prediction. It is merely a plausible base case from which to assess the effects of changes in cocaine-control policies.

If cocaine-control programs are assumed not to change from their 1992 levels, the base-case incidence scenario results in a slight increase in cocaine consumption through 1998 followed by a decrease to 94 percent of the 1992 level by 2007 (indicated by the heavy line in Figure C.2).

To judge the sensitivity of the base-case projections to the incidence scenario, we examined two other scenarios: a higher-incidence scenario, with incidence remaining constant at 0.988 million per year, and a lower-incidence scenario, with incidence declining to zero by 2007 (see Figure C.1).

Under the higher-incidence scenario, consumption would increase over the entire 15-year period, and under the lower-incidence scenario, consumption would rise only briefly before falling to 73 percent of the 1992 level by 2007 (see Figure C.2) This is the result of the inertia of heavy use. The annual total outflow rate of heavy users is small (only an estimated 6 percent), so it takes many years for a lower inflow rate to significantly affect the number of heavy users.

PRICE ELASTICITY OF DEMAND

This analysis assumes that the (total, long-run) price elasticity of demand for cocaine is −0.5, meaning that demand decreases by 0.5 percent when price increases by 1 percent. This assumption seems reasonable, given the range of estimates for the

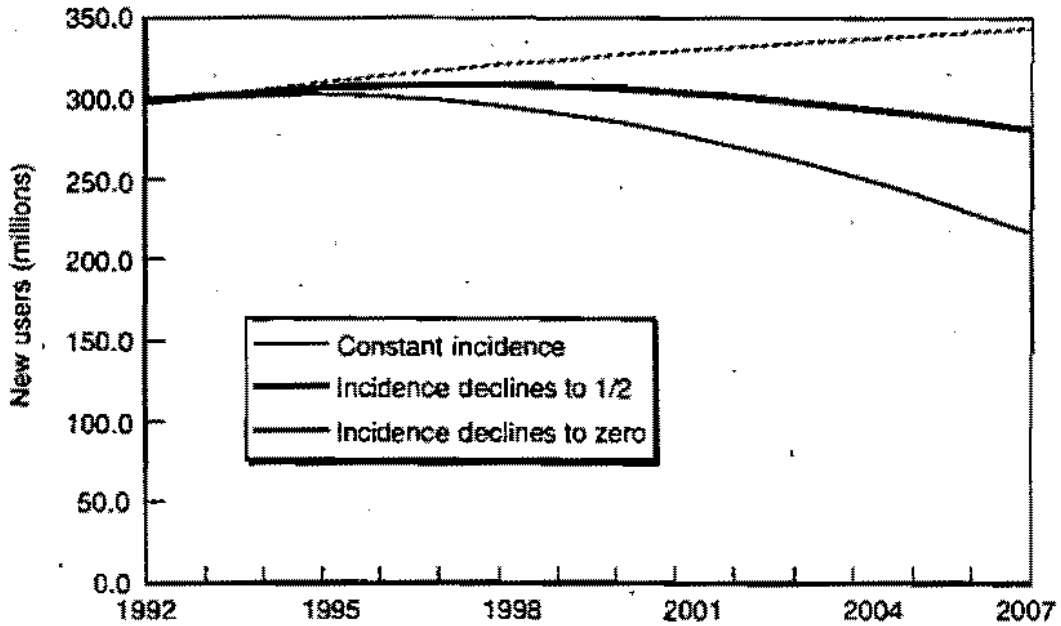

Figure C.2—Consumption Projections

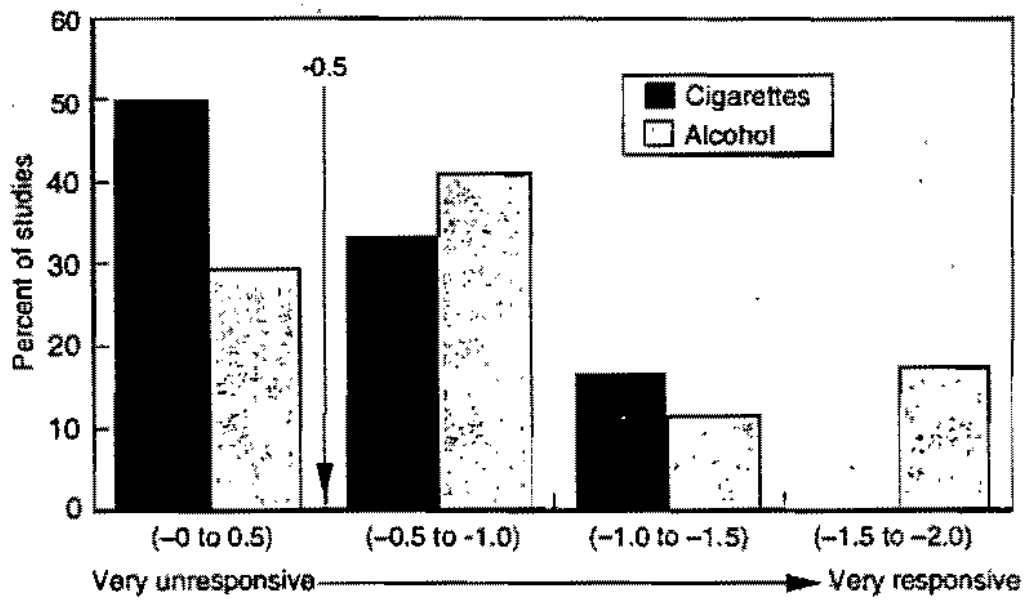

Figure C.3—Estimated Demand Response to Price for Cigarettes and Alcohol

price elasticity of cigarettes and alcohol presented in Figure C.3 (Manning et al., 1991, Appendix F).

Additionally, this analysis estimates that half of this long-run price elasticity of demand is due to changed consumption per user,[7] and half is due to changes in inflows and outflows that cause the number of users to change over time.[8] In other words, if supply-control policy succeeds in raising the price of cocaine by 10 percent, only a 2.5 percent decrease in cocaine consumption occurs immediately. Then the consumption decrease gradually accumulates over time to a total of 5 percent as the number of users declines in response to decreased user inflows and increased user outflows. The pace of this long-run adjustment is slow, however.[9] A 10 percent price increase starting in 1993 would result in a 3.6 percent decrease in consumption by 2000 (8 years to go three-fourths of the way to the long-run decrease) and a 4.4 percent decrease in consumption by 2007 (15 years to go nine-tenths of the way to the long-run decrease).

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[7]We assume that light and heavy current cocaine users have the same responsiveness of consumption to price.

[8]Becker, Grossman, and Murphy (1991, p. 240) found that the price elasticity of demand for cigarettes in the short run is half that in the long run.

[9]The pace of adjustment is governed by the inflow and outflow rates in our dynamic model of demand (see Table C.2).

DEMAND-CONTROL PROGRAMS

In general, demand-control programs include prevention of new users from starting cocaine in the first place, efforts to persuade light users to quit before they escalate to heavy use, and treatment programs for heavy drug users. However, this analysis considers only the last category.

TYPES OF TREATMENT

Two principal kinds of treatment are currently available for heavy users of cocaine: outpatient treatment and residential treatment. Outpatient treatment is presumed to be offered for easier cases and residential treatment to be offered for harder cases. In addition, caseloads are presumed to be skewed toward easier cases when few heavy users are treated. In other words, we expect the proportion of residential treatments to increase as the proportion of all heavy users who are treated increases.

THEORY OF PROGRAM EFFECTS

Effect of Drug Dealer Imprisonment

To the extent that cocaine dealers are also cocaine users, imprisoning a cocaine dealer reduces demand by an incapacitation effect:

$$j = \frac{(Seizures)(ArrestRate)(PropLiDealer)(PrisonRate)}{(1,000,000)(LiBegUsers)} \qquad \text{(D.1)}$$

j = incapacitation rate of light users due to imprisonment of drug dealers (drug dealers in jail or prison who were light users before they entered jail or prison as a proportion of all light users)

Seizures = seizures of cocaine by domestic enforcement (metric tons)

ArrestRate = arrests of drug dealers per metric ton of cocaine seized

PropLiDealer = proportion of arrested drug dealers who are light cocaine users

PrisonRate = cell-years of imprisonment of drug dealers per arrest

LiBegUsers = light users at the beginning of the year (millions)

$$n = \frac{(Seizures)(ArrestRate)(PropHeDealer)(PrisonRate)}{(1,000,000)(HeBegUsers)} \tag{D.2}$$

n = incapacitation rate of heavy users due to imprisonment of drug dealers (drug dealers in jail or prison who were heavy users before they entered jail or prison as a proportion of all heavy users)

PropHeDealer = proportion of arrested drug dealers who are heavy cocaine users

HeBegUsers = heavy cocaine users at the beginning of the year (millions)

Effect of Treatment on Outflow rates

The outflow of heavy cocaine users caused by treatment programs is a weighted average of the outflows caused by outpatient and residential treatment. In the demand-control model, the additional outflow due to treatment is stated relative to the annual outflow that would occur without treatment.

$$k = x\frac{(OutAdd)(1-z) + (ResAdd)z}{f^* + g^*} \tag{D.3}$$

k = ratio of additional outflow rate due to treatment of heavy cocaine users to the reference outflow rate from heavy cocaine use

x = multiplier (for sensitivity analysis) of the estimated ratio of additional outflow rate to the reference outflow rate from heavy use of cocaine

z = residential treatments as a proportion of all treatments

OutAdd = additional outflow rate from heavy cocaine use (to either light use or non-use) of heavy users who receive outpatient treatment during the year

ResAdd = additional outflow rate from heavy cocaine use (to either light use or non-use) of heavy users who receive residential treatment during the year

Effect of Treatment on Current Consumption

In addition to causing the outflow from heavy cocaine use to increase, cocaine-control programs also cause consumption to decrease while clients are in treatment:

$$d = (OutDesist)(OutDur)(1-z) + (ResDesist)(ResDur)z \tag{D.4}$$

d = desistance rate (person-years that users stop using cocaine while they are in treatment programs, equal to the average treatment duration times the proportion of time in treatment that people are off drugs)

z = residential treatments as a proportion of all treatments

OutDesist = proportion of time during outpatient treatment that clients stop using cocaine

OutDur = average duration (in fractions of a year) of outpatient treatment

ResDesist = proportion of time during residential treatment that clients stop using cocaine

ResDur = average duration (in fractions of a year) of residential treatment

Budget for Treatment of Heavy Users

The total cost of cocaine treatment programs is the sum of the costs for outpatient and residential treatments. That cost increases as the proportion of all users treated increases, and as the proportion of treatments that are residential increases:

$$B = \left\{U\left[1 - z\right] + Rz\right\} tH \tag{D.5}$$

B = budget for outpatient and residential treatment of heavy cocaine users

z = residential treatments as a proportion of all treatments

t = proportion of heavy users treated (by either outpatient or residential treatment)

H = total number of heavy cocaine users at the start of the year

U = cost per outpatient treatment

R = cost per residential treatment

Mix of Treatment Types

As the proportion of heavy users treated increases, the proportion of hard-to-treat clients—those that require residential treatment—increases. The following specification assumes that the proportion of all treatments that are residential increases linearly with the proportion of all heavy users who are treated during a year. Note that since the cost of treatment is considerably higher for residential than for outpatient treatment, this specification establishes diminishing returns to treatment program budgets[1]:

$$z = v + (w - v)t \tag{D.6}$$

z = residential treatments as a proportion of all treatments

t = proportion of heavy users treated (by either outpatient or residential treatment)

v = low-proportion residential treatments (proportion of all treatments that are residential when essentially no treatments are offered)

w = high-proportion residential treatments (proportion of all treatments that are residential when all heavy users are offered one treatment a year)

[1] For additional description of this specification, see Eq. (D.12) and the discussion of that equation at the end of this appendix.

With this specification, both the number of residential treatments and the number of outpatient treatments become functions of the parameters v and w as well as of the proportion, t, of all heavy users that are given one treatment or the other.

$$ResTreat = \left[vt + (w - v)t^2\right]H \tag{D.7}$$

ResTreat = residential treatments of heavy users during a year

$$OutTreat = \left[(1 - v)t - (w - v)t^2\right]H \tag{D.8}$$

OutTreat = outpatient treatments of heavy users during a year

There are, however, reasonableness constraints on how the parameters v and w can be chosen. First, to make z an increasing function of t, w must be larger than v. This also guarantees that residential treatments increase as total treatments increase. However, an upper limit on w must be obeyed to guarantee that outpatient treatments increase as total treatments increase. The mix swings in the direction of residential, but outpatient treatment must share in the growth. Differentiating Eq. (D.8) with respect to t, evaluating the derivative at its maximum over the range $0 < t < 1$, which occurs at $t = 1$, and requiring the derivative to be positive completes the constraints on w:

$$v < w < \frac{1 + v}{2} \tag{D.9}$$

Solving for Treatment Rate as a Function of Treatment Budget

Substituting Eq. (D.6) into the budget equation, Eq. (D.5), shows that the budget is a quadratic function of treatment rate:

$$B = \left\{U\left[1 - v - (w - v)t\right] + R\left[v + (w - v)t\right]\right\} tH \tag{D.10}$$

Putting that quadratic equation into standard form:

$$(w - v)\left[R - U\right]t^2 + \left\{U + v\left[R - U\right]\right\}t - \frac{B}{H} = 0 \tag{D.11}$$

The solution is

$$t = \frac{-\left\{U + v\left[R - U\right]\right\} + \left[\left\{U + v\left[R - U\right]\right\}^2 + 4(w - v)\left[R - U\right]\left(\frac{B}{H}\right)\right]^{1/2}}{2(w - v)\left[R - U\right]} \tag{D.12}$$

Here, the diminishing-returns property of our treatment model becomes especially clear. As the treatment budget, *B*, increases (for a given number of heavy users, *H*) the square-root power on the term in large brackets makes the proportion of heavy users treated increase at a decreasing rate.

Actually, Eq. (D.12) is not quite the final step in computing the proportion of heavy users receiving treatment, because it is possible for the treatment budget to outstrip the number of heavy users available to be treated. Formally, we have:

$$t = \min(Trialt, Maxt) \tag{D.13}$$

Trialt = proportion of heavy users that can be treated by the available treatment budget, as estimated by Eq. (D.12)

Maxt = maximum proportion of heavy cocaine users at the start of a year that can be treated during the year

When the constraint $t < Maxt$ is binding, all the available treatment budget will not be spent. In that case, Eq. (D.5) must be used to calculate the actual total cost of treatments during the year in question.

EMPIRICAL ESTIMATES OF PROGRAM EFFECTS

The qualification in the earlier appendixes about the necessity to use estimates and approximations applies here as well. The reference year for our policy analysis is 1992, so we want demand-control program characteristics as of that year. However, the longitudinal studies that provide evidence on program effectiveness necessarily started many years ago. Therefore, prior-year information must be extrapolated into a consistent, unbiased, and as-accurate-as-possible but by-no-means-perfect representation of 1992.

The context of treatment effectiveness is the number of treatments of different kinds done each year. Table D.1 derives estimates of the number of cocaine treatments for both 1989 and 1992. During those three years, the number of treatments grew by an estimated 54 percent. Total cocaine treatments divide by type of treatment into 78 percent outpatient and 22 percent residential, and by type of institution into 61 percent public and 39 percent private.

The annual cost per client in outpatient treatment was $1,600 in 1980 ($2,722 in 1992 dollars), and the annual cost per client in residential treatment was $7,329 ($12,467 in 1992 dollars) (Hubbard et al., 1989, pp. 63, 68). However, the cost per client in treatment (cost per person-year or annual cost per space) is not the same as cost per admission (cost per person treated or cost per client). On average, treatment durations are less than a year, which means that each treatment space can serve more than one person during a year and the cost per admission is less than the cost per client in treatment (see Table D.2).

Table D.1

Number of Cocaine Treatments: 1989 and 1992

Type of Treatment	Type of Institution		
	Public	Private	All
	Thousands of Treatments During 1989		
Outpatient	164	105	269
Residential	47	31	78
Total	211	136	347
	Thousands of Treatments During 1992		
Outpatient	252	162	414
Residential	73	47	120
Total	325	209	534

SOURCE: National Institute on Drug Abuse (1989), Butynski (1990), ONDCP (1992b).

NOTES: During 1989, there were 606,000 public drug treatments (Butynski, 1990, pp. 41–42) and 996,000 total drug treatments (National Institute on Drug Abuse, 1989, p. 25); the difference of 390,000 represents private drug treatments. Public treatments for cocaine use numbered 211,000, 34.8 percent of total public drug treatments (Butynski, 1990, pp. 41–42). Applying the same percentage to all private drug treatments produces an estimate of 136,000 private cocaine treatments. Of public, non-alcohol, non-heroin drug treatments, 77.5 percent were outpatient and 22.5 percent were residential (Butynski, 1990, pp. 22-23); applying this distribution to both public and private cocaine treatments completes the top three rows of this table. From 1989 to 1992, real public expenditure on all drug treatment increased by 54 percent (ONDCP, 1992b, p. 214). Applying this growth rate to both public and private cocaine treatments produces the estimates in the last three rows of this table.

To convert cost per client in treatment to cost per admission, we multiplied the cost per client by average treatment duration. This yielded the following estimates: average cost per admission = $762 for outpatient treatment and $5,107 for residential treatment, in 1992 dollars. Across both outpatient and residential treatments, the average cost per treatment admission was $1,740.

The estimates in Table D.2 obey three relationships: Admissions times treatment duration equals person-years in treatment, admissions times cost per treatment equals total cost of treatments, and total cost divided by person-years in treatment equals cost per person-year. Together, those three relationships imply a fourth: Cost per person-year times treatment duration equals cost per admission.

Cocaine treatment programs are highly effective during treatment: An estimated 73 percent of heavy users in outpatient programs stop using cocaine while in treatment, and 99 percent of heavy users in residential treatment stop using cocaine while in treatment (Hubbard et al., 1989, p. 180).[2] Post-treatment effectiveness is much lower: 12.2 percent of heavy cocaine users who receive outpatient treatment stop heavy use because of the treatment they received, and 16.7 percent of heavy users

[2]For example, the year before outpatient (drug-free) treatment, 12.8 percent of those treated were heavy cocaine users; during treatment, only 3.5 percent were heavy cocaine users, making the desistance proportion (0.128 – 0.035)/0.12 = 0.73.

Table D.2

Characteristics of Cocaine Treatment Programs: 1992

Type of Treatment	Treatment Duration: 3 Months or Less	More Than 3 Months	All
Client Admissions During Year (millions)[a]			
Outpatient	0.264	0.150	0.414
Residential	0.066	0.054	0.120
All	0.330	0.203	0.534
Average Treatment Duration (years)[b]			
Outpatient	0.085	0.624	0.280
Residential	0.099	0.794	0.410
All	0.088	0.669	0.309
Person-Years in Treatment (millions)			
Outpatient	0.022	0.093	0.116
Residential	0.007	0.043	0.049
All	0.029	0.136	0.165
Cost per Admission ($)[c]			
Outpatient	231	1699	762
Residential	1234	9899	$107
All	431	3862	1740
Total Cost of Treatment ($ millions)			
Outpatient	61	254	315
Residential	82	531	613
All	143	785	928
Cost per Person-Year in Treatment ($)			
Outpatient	2,722	2,722	2,722
Residential	12,467	12,467	12,467
All	4,931	5,775	5,626

SOURCE: Burynski (1990), Hubbard et al. (1989).

[a]Estimates of total outpatient and total residential cocaine treatments from Table D.1 distributed by length of treatment, using the proportions reported in Hubbard et al. (1989, p. 95).

[b]Hubbard et al. (1989, p. 95).

[c]Hubbard et al. (1989, pp. 63, 68); cost estimates updated to 1992 using the CPI.

who receive residential treatment stop heavy use because of the treatment they received (see Tables D.3 and D.4).

These estimates of post-treatment effects are conservative (potential underestimates) in that clients receiving treatments that last less than 3 months are used as the "control group" in the calculations of treatment effect in Tables D.3 and D.4. In other words, treatments lasting less than 3 months are assumed to have no effect, and the behavior of clients who receive those treatments is used to estimate what would happen in the absence of treatment. To the extent that treatments lasting less than 3 months have some effect, the calculation underestimates the effectiveness of cocaine treatments.

Table D.3

Effectiveness of Treating Heavy Cocaine Users: Outpatient Treatment

Time Since Treatment	Treatment Duration: 3 Months or Less	More than 3 Months	All[a]
	Clients Still Heavy Users per 1000 Treated		
1 year	635	633	634
2 years	429	227	356
3 years	735	438	627
4 years	735	438	627
5 years	735	438	627
	Clients Still Heavy Users if No Treatment Received[b]		
1 year	635	635	635
2 years	429	429	429
3 years	735	735	735
4 years	735	735	735
5 years	735	735	735
	Ratio		
1 year	1.000	0.997	0.999
2 years	1.000	0.529	0.830
3 years	1.000	0.596	0.854
4 years	1.000	0.596	0.854
5 years	1.000	0.596	0.854
Average	1.000	0.663	0.878
	Additional Outflow Due to Treatment (%)		
Rate	0.0	33.7	12.2

SOURCE: Hubbard et al. (1989, p. 180). The numbers in this table for years 3 to 5 are identical because the source reports only the average result over those years.

[a]63.8 percent, 3 months or less; 36.2 percent, more than 3 months (Hubbard et al., 1989, p. 95).

[b]Clients receiving 3 months or less treatment were used as the control group.

The following summary of the preceding discussion highlights the specific parameter estimates used by the demand-control model. In 1992, 534,000 of the 1,688,000 heavy cocaine users at the start of the year, or 31.64 percent, received drug treatment during the year ($t^* = 0.3164$), 77.53 percent of those receiving treatment got outpatient treatment, and 22.46 percent got residential treatment ($OutTreat = 0.414$ million, $ResTreat = 0.120$ million, $z^* = 0.2247$).

The proportion of the residential treatments (22.46 percent) is not constant in our model, however. As Eq. (D.6) specified, the proportion of residential treatments increases as the proportion of all heavy users increases. That formula has two parameters, v and w. The parameter v is the proportion of residential treatments when very few heavy users are treated, and w is the proportion of residential treatments when all heavy users are treated once a year.

Table D.4

Effectiveness of Treating Heavy Cocaine Users: Residential Treatment

Time Since Treatment	Treatment Duration: 3 Months or Less	More than 3 Months	All[a]
	Clients Still Heavy Users per 1000 Treated		
1 year	650	562	611
2 years	340	290	318
3 years	741	348	565
4 years	741	348	565
5 years	741	348	565
	Clients Still Heavy Users if No Treatment Received[b]		
1 year	650	650	650
2 years	340	340	340
3 years	741	741	741
4 years	741	741	741
5 years	741	741	741
	Ratio		
1 year	1.000	0.865	0.939
2 years	1.000	0.853	0.934
3 years	1.000	0.470	0.736
4 years	1.000	0.470	0.736
5 years	1.000	0.470	0.736
Average	1.000	0.625	0.833
	Additional Outflow Due to Treatment (%)		
Rate	0.0	37.5	16.7

SOURCE: Hubbard et al. (1989, p. 180). The numbers in this table for years 3 to 5 are identical because the source reports only the average result over those years.

[a]55.3 percent, 3 months or less; 44.7 percent, more than 3 months (Hubbard et al., 1989, p. 95).

[b]Clients receiving 3 months or less treatment were used as the control group.

Solving Eq. (D.6) yields the parameter, v, as a function of w, as well as the values of t and z in the reference situation:

$$v = \frac{z^* - wt^*}{1 - t^*} \tag{D.14}$$

Making the assumption that approximately 50 percent of all treatments would have to be residential if all heavy users were treated during a year ($w = 0.5000$), and using the reference-year estimates that $t^* = 0.3164$ and $z^* = 0.2247$, this formula shows that only 10.07 percent of all treatments would be residential if almost no heavy users were treated during a year ($v = 0.0973$). These estimates for w and v obey the inequalities in Eq. (D.9), because $0.0973 < 0.5000 < 0.5487$.

The average duration of outpatient treatment is 0.280 years, and the average duration of residential treatment is 0.410 years. The average cost per outpatient treatment is $762, and the average cost per residential treatment is $5,107. While in treatment, 73 percent of outpatient clients and 99 percent of residential clients stop using cocaine. The additional outflow from heavy cocaine use caused by treatment is 12.2 percent for outpatient treatment and 16.7 percent for residential treatment.

The remaining parameter estimates needed for the demand-control model describe cocaine use by cocaine dealers. The analysis assumes that three-fourths of cocaine dealers use cocaine, and that they are divided evenly between light and heavy users. Consequently, the estimated proportion of arrested cocaine dealers is the same for light and heavy users, 0.375.

THE COCAINE-CONTROL MODEL

This appendix documents the computer program used in this analysis. The program is written as an Excel spreadsheet. The spreadsheet uses range names for variables and linear logic, so it is possible to produce a listing of the calculation steps, analogous to that from traditional processing languages. The listing of the steps in our program constitutes the bulk of this appendix.

MODEL OVERVIEW

The computer model used to evaluate the cost-effectiveness of alternative cocaine-control programs has two levels: a core market-equilibrium level and an outer control-program level (see Figure E.1).

The model's first level balances market supply and demand. Cocaine producers react to seizures and sanctions by increasing gross production and by increasing prices. Cocaine consumers as a group react to treatment programs and price increases by decreasing inflows to cocaine use and increasing outflows from cocaine use, causing a decline in the number of drug users. Also, current cocaine users in any given year react to treatment programs and price increases by consuming less

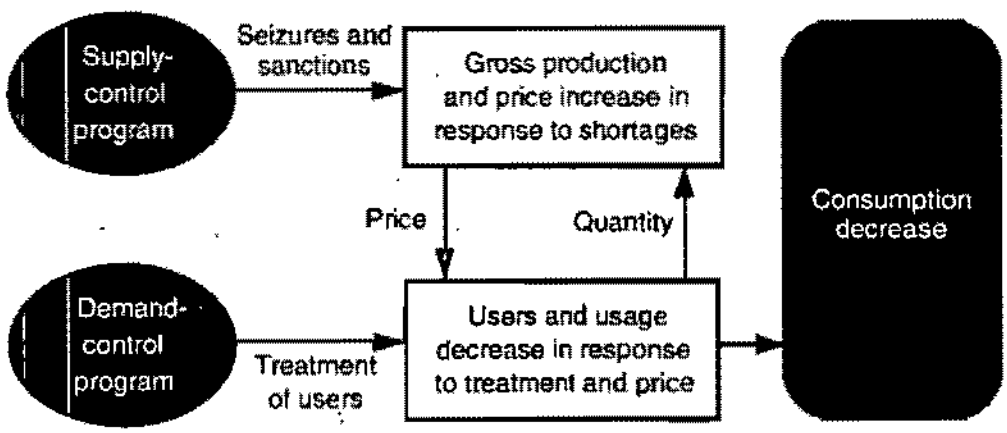

Figure E.1—Logical Structure of Cocaine-Control Model

cocaine. This part of the model iterates until supply and demand are in equilibrium in each of 15 projection years.

The model's second level assesses the consumption decrease caused by specific changes in supply-control and/or demand-control programs. Seizures and financial sanctions from supply-control programs affect cocaine producers, and drug-treatment programs affect cocaine users. Consumption decreases, in turn, have a feedback effect on subsequent years' control programs. For example, the costs of supply-control programs depend in part on the size of the program relative to the size of the cocaine market—so the previous year's control programs affect this year's program costs.

The general idea of the model is the familiar microeconomics diagram of a supply curve intersecting a demand curve, albeit with an unfamiliar twist (see Figure E.2).[1]

The unfamiliar aspect of Figure E.2 is that the supply curve slopes downward. This happens because as suppliers increase the volume of business, the cost of a given amount of control sanctions is diluted, causing the price per unit product to fall.[2]

It is the *industry's* supply curve, not the *individual supplier's* curve, that has a downward slope in our model. The individual supplier's curve is presumed to be flat—that

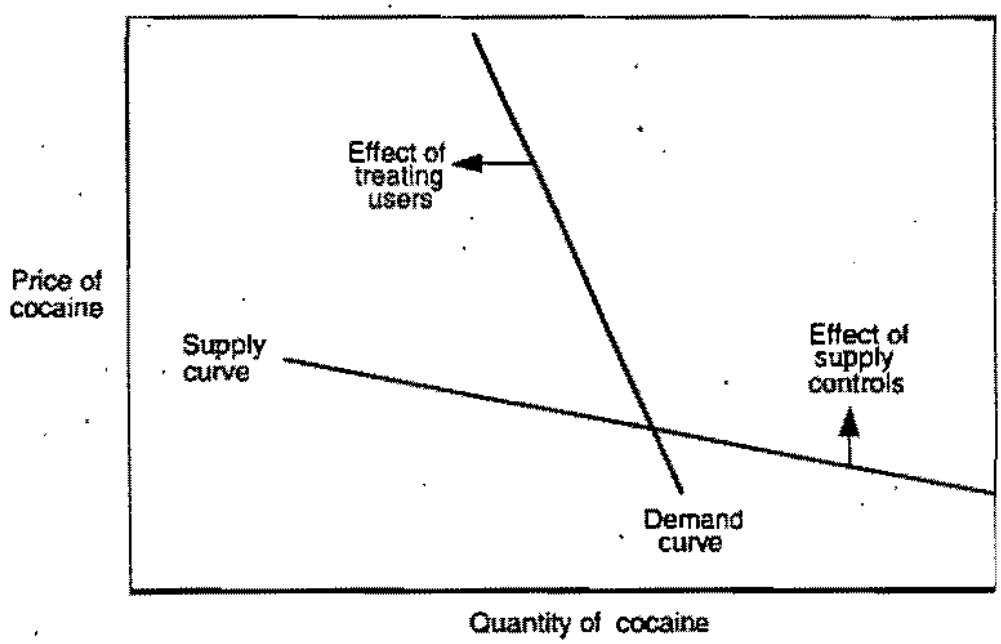

Figure E.2—How Cocaine-Control Programs Work

[1]This figure is qualitatively correct, but no attempt has been made to make it quantitatively exact. The cocaine-control model is too complex to be represented by a single diagram.

[2]For a brief discussion of this point, see Appendix A (at Eq. (A.5)); for an extended discussion, see Caulkins (1990).

is, we assume that expanding or contracting an individual supplier's volume of business does not in itself change the unit cost of supplying cocaine. However, if the total volume of business across all cocaine suppliers increases, then a given amount of supply control gets spread over a larger amount of product, and this external economy lowers the industrywide supply curve.

The importance of the distinction between individual and industry supply curves is compactly explained by Samuelson (1973, p. 477):

> It is not true that *downward*-sloping Marginal Cost curves of competitive firms can serve as their supply curves—for the very good reason that their profits will be at a minimum along such curves and they will rush away in either direction from such points. As a result one or a few firms will tend to expand and the remaining firms will tend to contract. Thus lasting decreasing costs that are *internal* to firms implies destruction of perfect competition. So it is wrong to talk of decreasing supply curves in such a case, or of competitive supply at all.
>
> There is, however, the possibility that *external economies* could prevail in an industry. In such cases expansion of *industry Q* [quantity] could *shift* downward the cost curves of *single firms*; and in the complicated adding of the resulting supplies of all firms, the industry supply curve could end up as downward-sloping.

In our model, the price elasticity of supply (percentage change in the supply of cocaine per 1 percent increase in price) depends on the choice of the parameter p, i.e., the proportion of seizure cost due to the amount of cocaine seized relative to total cocaine supplied as opposed to seizure cost due to the absolute amount of cocaine seized. In other words, p is the proportion of supply control's effect that is proportional to total production, as opposed to being spread over total production. As p increases, for a given enforcement budget, the amount of cocaine seized becomes more proportional to production levels, and the supply curve gets flatter.[3] Table E.1 presents the price elasticities of supply that correspond to different values of the parameter p, as estimated by our model.[4]

This analysis assumes that $p = 0.5$, making the price elasticity of supply −3.6, which gives the supply curve a slight downward slope. However, that choice is not crucial to the cost-effectiveness results of this analysis. The sensitivity analysis of the *proportion relative costing*, p, in Appendix F shows that this parameter (and hence the price elasticity of supply) has only a small effect on the cost-effectiveness of supply control relative to treatment.

The arrows in Figure E.2 indicate broadly how the cocaine-control model works. Supply-control programs increase the cost of supplying cocaine, which pushes the supply curve up, causing price to increase, which makes the quantity consumed decrease as the intersection of the supply and demand curve moves upward and to the

[3]That is, the percentage decrease in supply gets larger for a given price increase, i.e., the price elasticity of supply takes on a larger negative value.

[4]Even with p equal to 1.0, the supply curve is not perfectly flat (i.e., the supply elasticity is not infinitely large). This happens because *seizure costs* are only a part of all enforcement costs. Other costs (such as court and incarceration costs of arrested drug dealers) are always proportional to the absolute amount of enforcement, so total enforcement cost can never be entirely proportional to production level.

Table E.1

Estimates of the Price Elasticity of Supply

Proportion of Seizure Cost Due to Relative Size of Seizure, p	Price Elasticity of the Supply of Cocaine
0.0	−2.6
0.1	−2.7
0.2	−2.8
0.3	−3.0
0.4	−3.3
0.5	−3.6
0.6	−4.0
0.7	−4.5
0.8	−5.3
0.9	−6.6
1.0	−8.9

SOURCE: Runs of the cocaine-control model.

left. Demand-control programs decrease the quantity demanded, which pushes the demand curve to the left, causing quantity to fall and price to rise (because of the downward-sloping supply curve). Again, the intersection of the demand and supply curves (which identifies the market equilibrium) moves upward and to the left. What differs is the amount the price changes relative to the amount consumption changes.

SUMMARY MEASURES

Present Value of Consumption Changes

The cocaine-control model traces the effects of control programs on cocaine consumption for 15 projection years, 1993 to 2007. However, for cost-effectiveness comparisons, the 15 years of changes in annual cocaine consumption (resulting from additional control expenditure in year 1) need to be combined into a single measure. That measure is the present value (using a 4 percent real discount rate) of the 15 years of consumption change expressed as a percentage of baseline consumption in year 1.[5]

$$\text{\% consumption change} = 100\frac{\sum_{y=1}^{15}\left[D(y) - C(y)\right]\left[\frac{1}{1+r}\right]^{y}}{C(1)} \qquad \text{(E.1)}$$

$C(y)$ = base-case consumption of cocaine in year y

$D(y)$ = consumption of cocaine in year y, given additional control expenditure in year 1

[5]See Chapter One for a discussion of the reasons benefits should be discounted, just as costs are, in cost-effectiveness analyses.

$C(1)$ = total base-case consumption of cocaine in year 1
r = real discount rate

If all the consumption change occurred in year 1, this summary measure of effectiveness would be the percent change in year 1 consumption resulting from the additional expenditure on control in year 1. The actual consumption changes resulting from a year 1 increase in control are, of course, spread out over time. Taking the present value of the 15 years of changes aggregates them into an equivalent year 1 change in consumption.

Alternative Evaluation Criteria

In addition to the consumption measure of program performance, the cocaine-control model also counts cocaine users and estimates the cost of crime and lost productivity due to cocaine use. Like consumption, both of these measures are estimated for 15 projection years and summarized by an annualized value.

The formula for estimating the social cost of cocaine (using the assumptions that the cost of crime caused by cocaine use is proportional to expenditure and the lost productivity caused by cocaine use is proportional to consumption) is:

$$SocietalCost = [CrimeCost]P(\bar{B})C(\bar{B}) + [ProdCost]C(\bar{B}) \qquad \text{(E.2)}$$

$SocietalCost$ = cost of crime and lost productivity due to cocaine use (millions of dollars per year)
$CrimeCost$ = dollar cost of crime due to cocaine use per dollar expenditure on cocaine
$ProdCost$ = millions of dollars of lost productivity due to cocaine use per metric ton of cocaine consumed
$\bar{B}$ = vector of annual control-program budgets
P = price of cocaine (dollars per gram)
C = consumption of cocaine (metric tons per year), a function of the vector of annual control program budgets

Estimates of the two cost factors are $CrimeCost$ = \$0.19480 per dollar expenditure on cocaine (\$7,324 million annual crime cost, from Table 5.2, divided by \$129.2 per gram price of cocaine times 291 metric tons of cocaine consumed per year, from Table A.8); and $ProdCost$ = \$67.6289 million per metric ton consumption (\$19,680 million annual lost productivity, from Table 5.2, divided by 291 metric tons of cocaine consumed per year).

This equation can be rewritten as the product of two factors, one that varies with price and another that varies with consumption:

$$SocietalCost = \left\{[CrimeCost]P(\bar{B}) + [ProdCost]\right\}C(\bar{B}) \qquad \text{(E.3)}$$

Since treatment programs reduce consumption while hardly affecting price, it is not surprising that the social-cost measure evaluates treatment programs essentially the same as the consumption measure does. However, supply-control programs increase price while decreasing consumption, which explains why the social-cost measure rates supply-control programs lower (relative to treatment programs) than the consumption measure does.

MODEL DETAILS

The Excel spreadsheet implementation of the cocaine-control model has three modules, each on a separate spreadsheet (see Figure E.3). The core module (ANNUAL.XLS) is the market-equilibrium model used each year to balance supply and demand. A policy module (INOUT.XLS) contains 15 years of control-program policy choices sent one year at a time to the annual market module, and 15 years of results from that market module. Finally, a macro module (MACRO.XLM) contains the instructions that guide model operation.

Inputs defining the behavior of cocaine suppliers and cocaine users are listed in Figures E.4 through E.6. The inputs in these tables are on the ANNUAL.XLS spreadsheet, because they are the same for all projection years. The key parameters listed in Figure E.4 are six of the seven parameters covered by the sensitivity analysis in Appendix F (the seventh parameter analyzed there is the real discount rate).

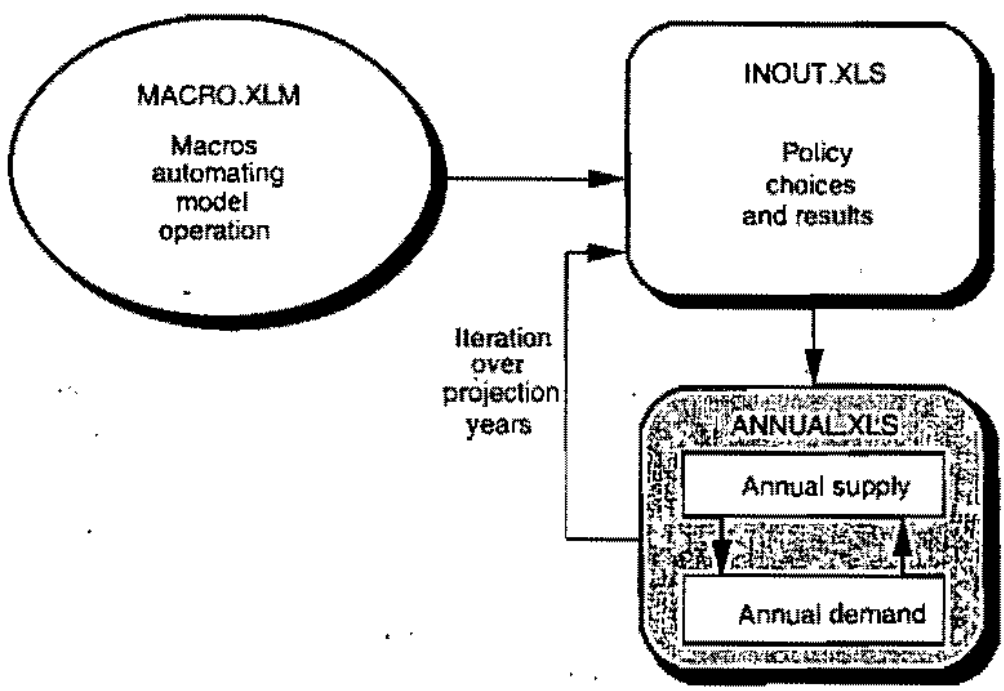

Figure E.3—Spreadsheet Implementation of Cocaine-Control Model

KEY PARAMETERS FOR SENSITIVITY AND THRESHOLD ANALYSES	Parameter Name	Value
Elasticity of demand for cocaine with respect to retail price of cocaine	e	-0.50
Elasticity of production cost with respect to supply seizures	h	0.44
Ratio of marginal to average productivity of supply control	m	0.80
Proportion of seizure cost due to relative size of seizure	s	0.50
High proportion of residential treatment (proportion treatments residential when all heavy users treated each year)	w	0.50
Multiplier of additional outflow from heavy use, due to treatment	x	1.00

Figure E.4—Input of Key Parameters

SUPPLY PARAMETERS	Parameter Name	Value
Source Country		
Cost of cocaine base input per gross product of cocaine ($M/mt)	SoInputPrice	2.0504
Gross product in source country in reference situation (mt)	SoRefG	654
Cost of production process in reference situation ($M/mt)	SoRefK	1.4068
Reference total price of this stage's product ($M/mt)	SoRefPrice	4.41
Reference level of product seizures (mt)	SoRefSeize	117.00
Reference $M assets seized per mt product seized	SoAssetSanctRate	0.0598
Reference arrests of drug traffickers per mt product seized	SoArrestRate	306.8
Reference cell-years of imprisonment per drug-trafficker arrest	SoPrisonRate	0.0500
Cost to producers of drug trafficker arrests: $M/arrest	SoArrestSanctRate	0.0021
Cost to producers of drug trafficker imprisonment: $M/cell-year	SoPrisonSanctRate	0.0129
Transit		
Gross product in transit in reference situation (mt)	TrRefG	537
Cost of production process in reference situation ($M/mt)	TrRefK	8.853
Reference total price of this stage's product ($M/mt)	TrRefPrice	17.00
Reference level of product seizures (mt)	TrRefSeize	94.00
Reference $M assets seized per mt product seized	TrAssetSanctRate	2.7021
Reference arrests of drug traffickers per mt product seized	TrArrestRate	46.8
Reference cell-years of imprisonment per drug-trafficker arrest	TrPrisonRate	0.74
Cost to producers of drug trafficker arrests: $M/arrest	TrArrestSanctRate	0.0064
Cost to producers of drug trafficker imprisonment: $M/cell-year	TrPrisonSanctRate	0.0386
Domestic		
Gross product in domestic market in reference situation (mt)	DoRefG	443
Cost of production process in reference situation ($M/mt)	DoRefK	51.928
Reference total price of this stage's product ($M/mt)	DoRefPrice	129.20
Reference level of product seizures (mt)	DoRefSeize	152.00
Reference $M assets seized per mt product seized	DoAssetSanctRate	3.3694
Reference arrests of drug traffickers per mt product seized	DoArrestRate	1232.9
Reference cell-years of imprisonment per drug-trafficker arrest	DoPrisonRate	0.74
Cost to producers of drug trafficker arrests: $M/arrest	DoArrestSanctRate	0.0064
Cost to producers of drug trafficker imprisonment: $M/cell-year	DoPrisonSanctRate	0.0368
CHARACTERSITICS OF SUPPLY-CONTROL PROGRAMS		
Source		
Seizure cost per metric ton of cocaine seized in reference situation ($M/mt)	SoW	7.22
Fraction of asset seizures salvaged (forfeited to government)	SoForfeitRate	0.394
Public cost per drug trafficker arrest ($M/arrest)	SoArrestCostRate	0.0004
Public cost of imprisoning drug traffickers ($M/cell-year)	SoPrisonCostRate	0.0077
Transit		
Seizure cost per metric ton seized in reference situation ($M/mt)	TrW	18.33
Fraction of asset seizures salvaged (forfeited to government)	TrForfeitRate	0.394
Public cost per drug trafficker arrest ($M/arrest)	TrArrestCostRate	0.0013
Public cost of imprisoning drug traffickers ($M/cell-year)	TrPrisonCostRate	0.0232
Domestic		
Seizure cost per metric ton seized in reference situation ($M/mt)	DoW	40.92
Fraction of asset seizures salvaged (forfeited to government)	DoForfeitRate	0.394
Public cost per drug trafficker arrest ($M/arrest)	DoArrestCostRate	0.0013
Public cost of imprisoning drug traffickers ($M/cell-year)	DoPrisonCostRate	0.0232

Figure E.5—Inputs to Supply Model

DEMAND PARAMETERS	Parameter Name	Value
Annual rate at which light users quit	LiQuitRate	0.150
Annual rate of light user progression to heavy use	ProgRate	0.024
Annual rate of heavy user regression to light use	RegressRate	0.040
Annual rate at which heavy users quit	HeQuitRate	0.020
Consumption of cocaine by light users (grams/year) at reference price	LiConsRate	16.42
Consumption of cocaine by heavy users (grams/year) at reference price	HeConsRate	116.93
Proportion of arrested drug dealers who are light cocaine users	PropLiDealer	0.375
Proportion of arrested drug dealers who are heavy cocaine users	PropHeDealer	0.375
Societal cost of crime caused by cocaine ($ per dollar user expenditure on cocaine)	CrimeCost	0.19460
Societal cost of lost productivity due to cocaine ($ per metric ton of cocaine consumed)	ProdCost	67.0289
CHARACTERISTICS OF DEMAND-CONTROL PROGRAMS		
Cost per outpatient treatment ($)	OutCost	762
Cost per residential treatment ($)	ResCost	5107
Proportion heavy users treated during year in reference situation	Reft	0.3154
Proportion of all treatments of heavy users that are residential	Retz	0.2947
Additional outflow rate from heavy cocaine use (to light or non use) of heavy users who receive outpatient treatment	OutAdd	0.122
Additional outflow rate from heavy cocaine use (to light or non use) of heavy users who receive residential treatmen	ResAdd	0.167
Incapacitation rate of light users due to imprisonment of drug dealers in reference situation	Reij	0.00946
Incapacitation rate of heavy users due to imprisonment of drug dealers in reference situation	Reih	0.03079
Proportion of time during outpatient treatment that clients stop using cocaine	OutDesist	0.73
Proportion of time during residential treatment that clients stop using cocaine	ResDesist	0.99
Average duration (in fraction of year) of outpatient treatment	OutDur	0.25
Average duration (in fraction of year) of residential treatment	ResDur	0.41
Maximum feasible proportion of heavy users treated during a year	Maxt	1.00

Figure E.6—Inputs to Demand Model

The incidence projection and the budget-level policy parameters for a given projection year, shown in Figure E.7, come from the INOUT.XLS spreadsheet because they vary by projection year. The ANNUAL.XLS spreadsheet gets used over again each year, so a given year's inputs and outputs are not preserved there. Inputs and outputs for all years are recorded side by side on the INOUT.XLS spreadsheet.

Figures E.8 and E.9 contain the calculations in the model needed to produce the outputs in Figure E.10 from the inputs in Figures E.4 through E.7. In all cases, the variable definitions are given on the left, and the variable names (and values) are given on the right. For the calculations, the formula generating the result is shown in the center of the display.

The variable names for the Excel program are the letter symbols, or adaptations of those symbols, used for the variables in the algebra in Appendixes A through D, or they are the word names used for variables in those appendixes, or they are additional (self-explanatory) word names used in place of the letter symbols of Appendixes A through D. The potential confusion of two names for the same item (the letter symbol in Appendixes A through D and word name in the model) is more than offset by the advantages of having compact, easy-to-scan algebra equations in the theoretical appendixes and directly readable computation equations in the computer program.[6] Only the variables in Appendixes A through D and in the text of Appendix

[6]Excel does not distinguish between lowercase and uppercase letters as range names, so it was not possible (even if it had been desirable) to name all the computer variables by their letter symbols in the theoretical appendixes.

	Parameter Name	Value
SCENARIO		
Incidence of new users (millions) in projection year	IncidenceInput	0.958
Program budget ($M) in projection year: source country control	SoBudget	871
Program budget ($M) in projection year: interdiction in transit	TrBudget	1705
Program budget ($M) in projection year: domestic enforcement	DoBudget	9474
Program budget ($M) in projection year: treatment of heavy users	HeBudget	928
RESULTS FROM LAST YEAR		
Light users at begining of year (from end of last year)	LiBegUsers	5.496
Heavy users at begining of year (from end of last year)	HeBegUsers	1.688

Figure E.7—Inputs for Specific Projection Year

Explanation	Formula Generating Result	Name of Result	Value
Source country production, net of non-US consumption			
Product	*This variable chosen by the computer program*	SoProduct	654
SoZ	SoW*((1-p)+p*SoRefG/SoProduct)	SoZ	7.22
SoV	SoAssetSanctRate*SoForfeitRate	SoV	0.02
SoA	SoArrestRate*SoArrestCostRate	SoA	0.13
SoY	SoArrestRate*SoPrisonRate*SoPrisonCostRate	SoY	0.12
SoDen	(SoZ-SoV+SoA+SoY)*m	SoDen	4.98
SoNum	(SoBudget*m)*SoRefSeize*(1-m)	SoNum	582.98
Seizures (mt)	SoNum/SoDen	SoSeizures	117
Net product (mt)	SoProduct - SoSeizures	SoNetProduct	537
Production cost ($M)	SoProduct*(SoInputPrice+SoRefK*(SoSeizures/SoRefSeize)*m)	SoProdCost	2281
Asset seizure sanction ($M)	SoSeizures*SoAssetSanctRate	SoAssetSanct	7
Arrest sanction ($M)	SoSeizures*SoArrestRate*SoArrestSanctRate	SoArrestSanct	77
Imprisonment sanction ($M)	SoSeizures*SoArrestRate*SoPrisonRate*SoPrisonSanctRate	SoPrisonSanct	23
Cost of net product ($M)	SoProdCost + SoAssetSanct + SoArrestSanct + SoPrisonSanct	SoNetCost	2368
Transportation to the United States			
Product	SoNetProduct	TrProduct	537
TrZ	TrW*((1-p)+p*TrRefG/TrProduct)	TrZ	16.33
TrV	TrAssetSanctRate*TrForfeitRate	TrV	1.06
TrA	TrArrestRate*TrArrestCostRate	TrA	0.05
TrY	TrArrestRate*TrPrisonRate*TrPrisonCostRate	TrY	0.80
TrDen	(TrZ-TrV+TrA+TrY)*m	TrDen	10.15
TrNum	(TrBudget*m)*TrRefSeize*(1-m)	TrNum	955.00
Seizures (mt)	TrNum/TrDen	TrSeizures	94
Net product (mt)	TrProduct - TrSeizures	TrNetProduct	443
Production cost ($M)	SoNetCost + TrProduct*TrRefK*(TrSeizures/TrRefSeize)*m	TrProdCost	7123
Asset seizure sanction ($M)	TrSeizures*TrAssetSanctRate	TrAssetSanct	254
Arrest sanction ($M)	TrSeizures*TrArrestRate*TrArrestSanctRate	TrArrestSanct	28
Imprisonment sanction ($M)	TrSeizures*TrArrestRate*TrPrisonRate*TrPrisonSanctRate	TrPrisonSanct	126
Cost of net product ($M)	TrProdCost + TrAssetSanct + TrArrestSanct + TrPrisonSanct	TrNetCost	7531
Domestic Distribution and Marketing			
Product	TrNetProduct	DoProduct	443
DoZ	DoW*((1-p)+p*DoRefG/DoProduct)	DoZ	40.92
DoV	DoAssetSanctRate*DoForfeitRate	DoV	1.33
DoA	DoArrestRate*DoArrestCostRate	DoA	1.54
DoY	DoArrestRate*DoPrisonRate*DoPrisonCostRate	DoY	21.20
DoDen	(DoZ-DoV+DoA+DoY)*m	DoDen	27.28
DoNum	(DoBudget*m)*DoRefSeize*(1-m)	DoNum	4145.68
Seizures (mt)	DoNum/DoDen	DoSeizures	152
Net product (mt)	DoProduct - DoSeizures	DoNetProduct	291
Production cost ($M)	TrNetCost + DoProduct*DoRefK*(DoSeizures/DoRefSeize)*m	DoProdCost	30534
Asset seizure sanction ($M)	DoSeizures*DoAssetSanctRate	DoAssetSanct	512
Arrest sanction ($M)	DoSeizures*DoArrestRate*DoArrestSanctRate	DoArrestSanct	1199
Imprisonment sanction ($M)	DoSeizures*DoArrestRate*DoPrisonRate*DoPrisonSanctRate	DoPrisonSanct	5353
Cost of net product ($M)	DoProdCost + DoAssetSanct + DoArrestSanct + DoPrisonSanct	DoNetCost	37598
Market Results			
Supply	DoNetProduct	Supply	291
Supply Price	DoNetCost / DoNetProduct	SupplyPrice	129.2

Figure E.8—Supply Model

E are in the Glossary. All variables used in the computer program are defined in Figures E.4 through E.10 (some are also in the Glossary because the same names are used in Appendixes A through D).

Explanation	*Formula Generating Result*	*Name of Result*	*Value*
Demand Price			
Price ($/kilo, i.e., $/gram)	*This variable chosen by the computer program*	Price	129.2
Ratio of price to reference price	Price / DoRefPrice	PriceRatio	1.000
Light-User Flows (millions of people per year)			
Progression to heavy use	LiBegUsers*ProgRate*PriceRatio^(e/4)	Progression	0.132
Light user quits	LiBegUsers*LiQuitRate*PriceRatio^(-e/4)	LiQuits	0.824
Incidence of new light users	IncidenceInput*PriceRatio^(e/4)	Incidence	0.988
Heavy-User Flows (millions of people per year)			
Low prop. residential treatment	(RatioW*RatR)/(1-RatR)	w	0.0873
Cost term A	OutCost+w*(ResCost-OutCost)	CostA	1185
Cost term B	(w-v)*(ResCost-OutCost)	CostB	1730
Trial prop. heavy users treated	(-CostA+(CostA^2+4*CostB*HeBudget/HeBegUsers)^0.5)/(2*CostB)	TrialT	0.3153
Prop. heavy users treated	min(TrialT, MaxT)	t	0.3153
Prop. residential treatments	v+(w-v)*t	z	0.2247
Outpatient treatments (M/Yr)	(1-z)*t*HeBegUsers	OutTreat	0.414
Residential treatments (M/Yr)	z*t*HeBegUsers	ResTreat	0.120
Add'l outflow/fail, outflow	x*(OutAdd*(1-z)+ResAdd*z)/(RegressRate+HeQuitRate)	k	2.202
Heavy user quits	HeBegUsers*HeQuitRate*((1+k*(1-RatR))*PriceRatio^(-e/4)	HeQuits	0.034
Regression to light use	HeBegUsers*RegressRate*((1+k*(1-RatR))*PriceRatio^(-e/4)	Regression	0.068
Users at End of Year			
Light users at end of year	LiBegUsers+Incidence-LiQuits-Progression+Regression	LiEndUsers	5.595
Heavy users at end of year	HeBegUsers-HeQuits+Progression-Regression	HeEndUsers	1.719
Consumption During Year (metric tons of cocaine)			
Incapacitation rate light users	DoSeizures*DoArrestRate*PropLiDealer*DoPrisonRate/(1000000*LiBegUsers)	i	0.0095
Incapacitation rate heavy users	DoSeizures*DoArrestRate*PropHeDealer*DoPrisonRate/(1000000*HeBegUsers)	h	0.0308
Desistance rate	OutDesist*OutDur*(1-z)+ResDesist*ResDur*z	d	0.2497
Light consumption (mt)	LiBegUsers*LiConsRate*((1-i)/(1-RatR))*PriceRatio^(e/2)	LiCons	90
Heavy consumption (mt)	HeBegUsers*HeConsRate*((1-v-d*t)/(1-RatR-d*RatR))*PriceRatio^(e/2)	HeCons	201
Total consumption (mt)	LiCons + HeCons	TotCons	291
Actual heavy-user treatment cost			
Treatment cost		TreatCost	928.0
Market Balance			
Excess supply	Supply - TotCons	ExcessSupply	0.0

Figure E.9—Demand Model

Result	Formula	Value
Users		
Light users at end of year (millions)	LiEndUsers	5.595
Heavy users at end of year (millions)	HeEndUsers	1.719
Total users at end of year (millions)	EndUsers	7.314
Treatments of heavy users		
Outpatient treatments (millions)	OutTreat	0.414
Residential treatments (millions)	ResTreat	0.120
Total treatments (millions)	OutTreat+ResTreat	0.534
Consumption		
Light-user consumption during year (metric tons)	LiCons	90.2
Heavy user consumption during year (metric tons)	HeCons	200.8
Total consumption during year (metric tons)	TotCons	291.0
Financial		
Retail price relative to reference-situation price	PriceRatio	1.000
Actual heavy-user treatment cost ($ millions)	TreatCost	928.0
Total control budget ($ millions)	SoBudget+TrBudget+DoBudget-TreatCost12975	
Light user expenditure on cocaine ($ billions)	LiCons*SupplyPrice	11880
Heavy user expenditure on cocaine ($ billions)	HeCons*SupplyPrice	25938
Total user expenditure on cocaine ($ billions)	TotCons*SupplyPrice	37598
Societal costs of crime caused by cocaine (millions)	CrimeCost*SupplyPrice*TotCons	7324
Societal costs of lost productivity caused by cocaine (millions)	ProdCost*TotCons	19680
Total societal costs of cocaine (millions)	(CrimeCost*SupplyPrice +ProdCost)*TotCons	27004

Figure E.10—Outputs

SENSITIVITY TO UNCERTAIN PARAMETERS

This appendix examines the effects of uncertainty about the correct values for seven parameters on the conclusion that treatment is more cost-effective than supply control. The first two, and the most important, parameters were analyzed in Chapter Four. This appendix extends that earlier analysis to five additional parameters, and to interactions among all seven.

PARAMETERS ANALYZED

The *price elasticity of demand* is the percentage change in demand caused by a 1 percent increase in the retail price of cocaine. This parameter is the fundamental link between supply-control programs and consumption. Supply-control programs increase the retail price of cocaine, and that price increase causes consumption to decrease—the amount of the consumption decrease being determined by the price elasticity of demand.[1]

The *additional outflow due to treatment* is the percentage of heavy users treated during a year who stop heavy use of cocaine during the year because of the treatment. They may regress to light use or they may stop cocaine use altogether, but they are no longer heavy users.[2] This percentage is in addition to the percentage of those in treatment who would have quit during the year without treatment.

The *processing cost elasticity* is the percentage increase in processing cost, at a given stage in the production of cocaine, per 1 percent increase in the level of supply control at that stage (with program level measured by cocaine seizures). Processing cost goes up as producers seek ways to reduce the losses caused by cocaine-control programs.[3]

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[1]For the precise role that the price elasticity of demand plays in the cocaine-control model, see the parameter e in Eqs. (C.4) through (C.10) in Appendix C.

[2]The added outflow due to treatment is a weighted average of the outflows due to outpatient and residential treatment. The sensitivity analysis is done with a parameter x that is a multiplier times the average outflow rate (12.5 percent in the reference situation). For the best estimate of the outflow rate, $x = 1.0$; for the low estimate, $x = 0.75$; for the high estimate, $x = 1.50$. See Eq. (D.3) in Appendix D.

[3]See the parameter h in Eq. (B.1) in Appendix B. In this report's analyses, the same value for this parameter is used in all production stages.

The *marginal productivity of supply control* is the ratio of marginal productivity of supply control to average productivity of supply control. It is the parameter that governs the degree of diminishing returns as the level of supply control increases (the smaller the parameter, the more returns diminish as control increases).[4]

The *proportion relative costing* is the parameter that specifies how much of the cost of cocaine seizures, at a given production stage, is due to the relative size of the amount seized (relative to gross production), as opposed to how much of the cost of cocaine seizures is due to the absolute amount of cocaine seized.[5] The larger this parameter, the less supply control's effects are diluted when the volume of cocaine production expands, and therefore the less the industry supply curve slopes downward.

The *high-proportion residential treatments* is the proportion of all treatments that must be residential if all heavy users at the start of a year are offered treatment during the year. The proportion of treatments that must be residential (as opposed to the less-expensive outpatient treatments) increases as more and more heavy users are treated, because increasingly difficult cases are usually encountered. This parameter governs the degree of diminishing returns as the level of treatment increases (the greater the parameter the more returns diminish as treatment increases).[6]

The *real discount rate* is the rate used to discount future costs and benefits into current dollars to enable outcomes in different years to be compared correctly.[7] The appropriate rate at which to discount future costs and benefits is always controversial in cost-benefit analyses. So, as is customary, we include the discount rate in this sensitivity analysis.

UNCERTAINTY RANGES

The ranges for the sensitivity analysis are presented in Table F.1. The middle value is labeled "best," indicating that it is the best estimate that could be obtained for this analysis. The low and high values define ranges judged by the authors to include all parameter values that have a reasonable chance of being the correct value. If a new study of one of these parameters were conducted tomorrow and the result fell somewhere else within the indicated range, we would not be surprised.

The widest range is for the proportion relative costing, reflecting the high degree of uncertainty about that parameter. Note that the ranges are not necessarily symmetrical about the best estimate. For example, the elasticity of demand with respect to price ranges from 25 percent below the best estimate to 50 percent above the best estimate.

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[4]See the parameter m in Eqs. (B.7) and (B.8) in Appendix B. In this report's analyses, the same value for this parameter is used in all production stages.

[5]See the parameter p in Eqs. (B.9) and (B.10) in Appendix B. In this report's analyses, the same value for this parameter is used in all production stages.

[6]See the parameter w in Eqs. (D.6) through (D.12) in Appendix D.

[7]See the parameter r in Eqs. (E.1) and (E.2) in Appendix E.

Table F.1

Ranges for Sensitivity Analysis

Parameter	Parameter Value		
	Low	Best	High
Price elasticity of demand	−0.38	−0.50	−0.75
Additional outflow due to treatment (%)	9.9	13.2	16.5
Processing cost elasticity	0.22	0.44	0.66
Marginal/average productivity of supply control	0.70	0.80	0.90
Proportion relative costing of seizures	0.10	0.50	0.90
High-proportion residential treatments	0.44	0.50	0.58
Real discount rate	0.02	0.04	0.08

SENSITIVITY RESULTS

Tables F.2 through F.8 present the sensitivity analyses of these parameters. The first row of each table shows the low, best, and high values of the parameter; the middle four rows give the annual cost (in millions of 1992 dollars) of reducing cocaine consumption by 1 percent,[8] and the bottom row shows the ratio of the domestic enforcement cost to treatment cost.

Table F.2

Cost of Reducing Consumption by 1 Percent: Effect of Price Elasticity of Demand
($ millions per year)

Control Program	Price Elasticity of Demand		
	−0.38	−0.50	−0.75
Source-country seizures	1084	783	472
Interdiction	505	366	222
Domestic enforcement	330	246	154
Treatment of heavy users	35	34	31
Enforcement/treatment	9.5	7.3	5.0

Table F.3

Cost of Reducing Consumption by 1 Percent: Effect of Additional Outflow Due to Treatment
($ millions per year)

Control Program	Additional Outflow Due to Treatment (%)		
	9.9	13.2	16.5
Source-country seizures	796	783	771
Interdiction	372	366	360
Domestic enforcement	250	246	242
Treatment of heavy users	43	34	27
Enforcement/treatment	5.7	7.3	9.0

[8]As in Chapters Two through Four, this is the cost in the first projection year of achieving consumption reductions over 15 projection years whose net present value is 1 percent of consumption in the first projection year.

Table F.4

Cost of Reducing Consumption by 1 Percent: Effect of Processing Cost Elasticity ($ millions per year)

	Processing Cost Elasticity		
Control Program	0.22	0.44	0.66
Source-country seizures	1009	783	632
Interdiction	510	366	286
Domestic enforcement	294	246	213
Treatment of heavy users	33	34	34
Enforcement/treatment	8.9	7.3	6.2

Table F.5

Cost of Reducing Consumption by 1 Percent: Effect of Marginal/Average Productivity ($ millions per year)

	Marginal/Average Productivity		
Control Program	0.70	0.80	0.90
Source-country seizures	944	783	667
Interdiction	425	366	322
Domestic enforcement	283	246	218
Treatment of heavy users	33	34	34
Enforcement/treatment	8.5	7.3	6.4

Table F.6

Cost of Reducing Consumption by 1 Percent: Effect of Proportion Relative Costing of Seizures ($ millions per year)

	Proportion Relative Costing of Seizures		
Control Program	0.10	0.50	0.90
Source-country seizures	799	783	761
Interdiction	369	366	364
Domestic enforcement	251	246	242
Treatment of heavy users	31	34	36
Enforcement/treatment	8.0	7.3	6.7

Table F.7

Cost of Reducing Consumption by 1 Percent: Effect of High-Proportion Residential Treatments ($ millions per year)

	High-Proportion Residential Treatments		
Control Program	0.44	0.50	0.58
Source-country seizures	780	783	788
Interdiction	365	366	368
Domestic enforcement	245	246	247
Treatment of heavy users	31	34	36
Enforcement/treatment	7.8	7.3	6.8

Table F.8

Cost of Reducing Consumption by 1 Percent: Effect of Real Discount Rate ($ millions per year)

	Real Discount Rate		
Control Program	0.02	0.04	0.08
Source-country seizures	727	783	886
Interdiction	340	366	414
Domestic enforcement	230	246	275
Treatment of heavy users	30	34	41
Enforcement/treatment	7.7	7.3	6.8

As we found in Chapter Four, which analyzed the first two of these parameters, the main qualitative results of this analysis are not affected by uncertainty about these parameter values. As in Chapter Four, the ratio in the bottom row of the tables is always greater than 1.0. This means that even when these parameters are varied to the extremes of their uncertainty ranges, there is never an instance where treatment is not more cost-effective than domestic enforcement. Moreover, the ranking of costs vertically down the columns is always the same. Source-country control costs more than interdiction, which costs more than domestic enforcement, which costs more than treatment.

Figure F.1 is a "tornado diagram" ranking the key parameters by their effect on relative program cost.[9] The scale at the bottom of the figure gives the cost of domestic enforcement as a multiple of the cost of treatment, when both programs are run at levels that achieve comparable reductions in cocaine consumption. In other words, the scale graphs the ratios in the bottom rows of Tables F.2 through F.8.

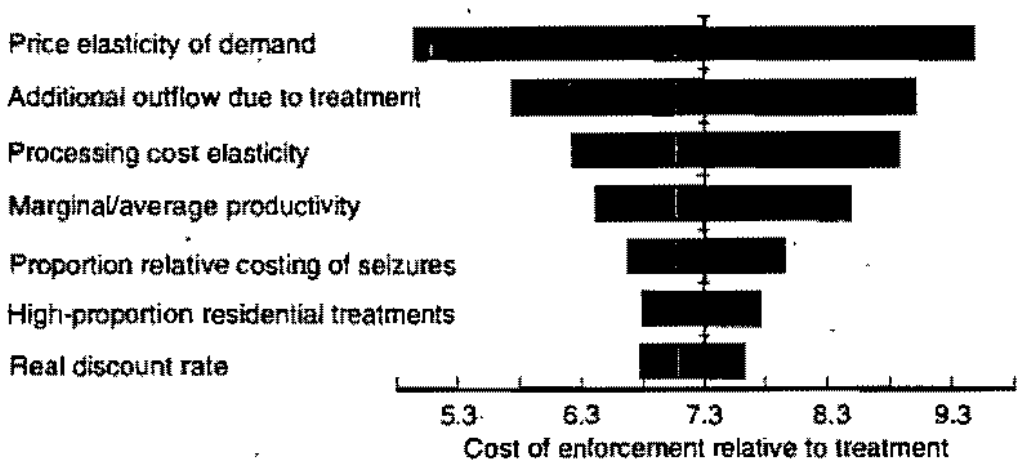

Figure F.1—Tornado Diagram Ranking the Degree to Which Uncertainty in Key Parameters Affects Relative Program Cost

[9]See Eschenbach (1992) for a general discussion of the uses of tornado diagrams in sensitivity analyses.

The horizontal scale is centered on the cost ratio, 7.3, which results when this study's best estimates are used for all parameters. The horizontal bars extend from the lowest to the highest cost ratio that occurs as a given parameter varies over the uncertainty range specified in Table F.1. Note, however, that the low cost ratio is not necessarily the result of using the low parameter value.

Not surprisingly, the parameters to which our results are most sensitive are the price elasticity of demand and the additional outflow rate due to treatment. The price elasticity of demand directly influences the effectiveness of supply-control programs, and the additional outflow rate is the most importanr parameter governing the effectiveness of treatment programs.

At the other extreme, the small effect of the real discount rate is also easy to understand. The discount rate would make a difference only if the time pattern of costs and benefits differed greatly among programs. In fact, both supply-control and treatment programs realize part of their benefits immediately (supply control's price increase causes current consumption to decrease, and treatment causes consumption to decrease while people are in treatment) and part with delay (as flows affected by the programs gradually change the number of cocaine users). With time patterns of program effects roughly similar, discounting does not have a big effect on relative program performance.

INTERACTION AMONG PARAMETERS

Tables F.2 through F.8 vary each parameter independently. What if all of them vary simultaneously? In particular, what if all take on the extreme values in Table F.1 that favor enforcement? Would enforcement still be more costly than treatment? The answer is yes, as Table F.9 shows. When all these parameters are set to the values in Table F.1 that favor enforcement, the ratio of domestic enforcement cost to treatment cost decreases from 7.3 to 2.3, a difference of –5.0; but 2.3 is still greater than 1.0, so enforcement is still more expensive than treatment.

Table F.9

Joint Effect of Parameters on Cost of Domestic Enforcement Relative to Treatment

	Deviation from 7.3 When Parameter	
Parameter Varied	Favors Enforcement	Favors Treatment
Price elasticity of demand	−2.4	2.2
Additional outflow due to treatment (%)	−1.6	1.7
Processing cost elasticity	−1.1	1.6
Marginal/average productivity of supply control	−0.9	1.2
Proportion relative costing of seizures	−0.6	0.7
High-proportion residential treatments	−0.5	0.5
Real discount rate	−0.5	0.3
Interaction effect when all parameters are varied	2.6	4.4
Total effect when all parameters are varied	−5.0	12.5

Moving in the opposite direction, if all these parameters take on the extreme values in Table F.1 that favor treatment, the ratio of domestic-enforcement cost to treatment cost increases from 7.3 to 19.8, a change of 12.5.

The interaction term is positive in both cases. The decreases in the cost ratio partially cancel, and the increases reenforce each other. The interaction terms can be most simply expressed by a multiplicative model. If each deviation favoring enforcement is expressed relative to 7.3, as in $1 - 2.4/7.3 = 0.67$, and all the resulting factors are multiplied together, the product is 0.31. Multiplying that product by 7.3 gives 2.3, which is 5.0 less than 7.3. Similarly, if each deviation favoring treatment is expressed relative to 7.3, as in $1 + 2.2/7.3 = 1.30$, and all the resulting factors are multiplied together, the product is 2.79. Multiplying that product by 7.3 gives 20.4, which is 13.1 greater than 7.3. The 13.1 deviation estimated from the multiplicative model is in close agreement with the 12.5 estimate in Table F.9, which was obtained by running the cocaine-control model.

This multiplicative model for combining the effects of several parameters, together with the information in Table F.1, can be used to estimate the effects of varying fewer than seven parameters jointly, or of varying them over different ranges than those in Table F.1. Table F.1 shows the independent effects, and the multiplicative model converts those independent effects into ratios and multiplies them together to obtain the joint effect. Theoretically, feedback loops in the model could make interactions among subjects of these variables, or over parts of the ranges analyzed here, behave differently than the multiplicative model. However, extensive sensitivity analysis not reported here showed that the multiplicative-model summary of sensitivity analysis results is a very good approximation to the results obtained from running the detailed cocaine-control model.

THRESHOLD ANALYSIS

The above sensitivity analyses establish ranges over which parameters can vary, then show how that variation affects results. "Threshold analysis" answers the opposite question: It shows the circumstances under which domestic enforcement becomes more cost-effective than treatment—that is, when the ratio of domestic-enforcement cost to treatment cost becomes less than 1.0.

Figure F.2 presents a threshold analysis for the first- and second-ranked parameters in Figure F.1: price elasticity of demand and the additional outflow due to treatment. For domestic enforcement to be more cost-effective than treatment, price elasticity must be sufficiently high and added outflow must be sufficiently low that together they exceed the heavy diagonal-line threshold in the upper left corner of the graph.

The two light diagonal lines in the upper left corner of the graph indicate how the threshold changes if all the other five parameters are set to the values in Table F.1 that favor treatment (upper light line) or to the values that favor enforcement (lower light line).

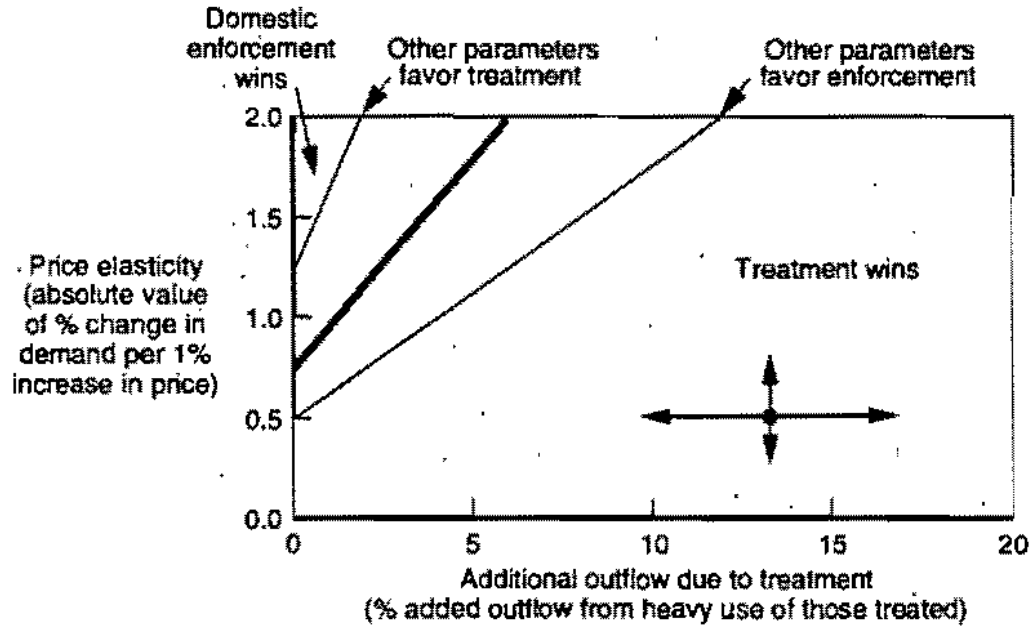

Figure F.2—Threshold Values of Price Elasticity and Additional Outflow, Where Domestic Enforcement Becomes More Cost-Effective Than Treatment

The solid dot in the diagram indicates the parameter values used in this analysis. The arrows leading out from the dot show the ranges in the sensitivity analysis. The cross formed by the arrows shows the uncertainty range of the parameters. The small size of the cross relative to the distance from the dot to any of the three threshold lines shows the robustness of the conclusion that treatment is more cost-effective than supply control.

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