Sowing Supply: Compensating Responses by Rural Coca Economies to Intervention in the Cocaine Market

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Abstract

In recent years, increased public awareness of the health and productivity costs associated with the use of cocaine and its potent derivative "crack" has served to heighten concern and renew debate over the most effective strategies for managing the drug problem. This paper presents a preliminary system dynamics model of the international cocaine trade. The initial model incorporates the various stages of the cocaine system from source country production to final consumption including: primary resource allocation and production; cocaine production and export; and U.S. demand, import, pricing, and consumption. The model is used to examine an ensemble of policies proposed by the National Strategy for Drug Control (White House 1989). Simulation results show the capacity of the system to exhibit a wide array of behavior modes depending on the type of intervention being applied and the aspect of the problem being targeted. Of particular interest from a policy standpoint is the implication of delays in physical and information flows for generating divergent short and long term policy results. Findings suggest a comprehensive approach combining demand and supply side policy leverage represents the most effective management strategy.

1. Introduction

During the past two decades, managing the drug problem has become a primary concern of U.S. citizens and policy makers. Increased public awareness of the health, productivity and social costs associated with the use of cocaine and its derivative "crack" has served to heighten concern and elicit increased government intervention and expenditure for controlling the international trade. This concern has renewed debate over the most effective types of policies for coping with the perennial drug abuse problem.

Traditionally, government intervention has emphasized drug interdiction policy to minimize the flow of cocaine before it reaches U.S. markets. Despite increased expenditures for these programs in recent years, cocaine consumption estimates and other indicators of domestic use exhibit dramatic growth. Evidence suggests that intervention on the supply side of the market alone is insufficient to cope with a complex system that also encompasses a resilient demand for cocaine. The limited success of past policies has prompted a recent National Drug Control Strategy (White House 1989) that proposes shifting resources to well known demand side policies including deterrence, preventive education, and rehabilitation/treatment.

This paper develops a preliminary system dynamics model to examine several of the policies proposed by the new strategy. The simulation model describes the commodity structure of the cocaine industry from production to final consumption. The basic structure of the model is similar to that presented in Meadow's (1969) study of commodity production cycles. The model treats explicitly: Andean agricultural resource allocation and production; cocaine production; import; export; and pricing; and US. demand determinants including the dynamics of user growth and addiction. Simulation results show the capacity of the system to exhibit a wide array of behavior modes that are sensitive to the type of intervention being applied, and the aspect of the problem being targeted. Of particular interest from a policy standpoint is the implication of delays in physical and information flows for generating divergent short and long term policy results. Findings suggest a comprehensive approach combining demand and supply side policy leverage as the most effective management strategy. Finally, the paper attempts to communicate practical insights for selecting among the available policy options.

The paper proceeds in the following order. The subsequent section presents a brief overview of the dynamic problem. Next, the simulation model is described, with the discussion focusing on the important causal relationships and system components. The fourth section discusses simulated behavior, examining model results under several alternative scenarios. The final section discusses findings, implications, and possible future developments for the project.

* Thanks and acknowledgements are due to George Richardson, David Andersen, Elena Alvarez and Sheila Clifford-Bova for helpful comments on the work presented here. Of course, all errors are mine.

2. The Problem

Manifestations of the cocaine problem are apparent from several different aspects within the cocaine system. There are concerns with growing supply and demand, as well as the resulting costs on society. From a domestic standpoint, the most publicized indicators being the growth of drug use and the user population. Two surveys, funded by the National Institute for Drug Abuse, The National Survey of Drug Abuse (1972-), and The National Survey of High School Seniors (1975-), have begun tracking patterns across several categories of cocaine use. Two distinct growth periods can be identified (Brower and Anglin 1987: 166-67). An initial growth phase can be traced from the inception of each study and ends approximately in 1979. During this period, use in all prevalence and age categories increased dramatically through the middle seventies, before leveling at the end of the decade. From 1979-1985, nearly all categories of use exhibited a common tendency toward subsiding. While most use categories stabilized, the overall expansion for the period remains significant. For example, the proportion of respondents in the 12-17 year old age group who reported ever using cocaine more than tripled. Moreover, the proportion in the same age group reporting use in the year and month prior to the survey nearly tripled. From 1975-1985, the percentage of high school seniors who reported daily use quadrupled (Brower and Anglin 1987: 166-67).

Since 1985, evidence from the National High School survey suggests the trend may be changing. The proportion of high school seniors reporting ever experimenting with the drug dropped thirty percent from 1985-1988 (NNICC Report 1988: 30-36). There are also signs of stabilization or reduction in several moderate use categories. These drops may be a sign that preventive education programs are having a positive effect on the problem, however, forecasting a permanent downturn is premature given the limited period of observation.

The dramatic growth in the popularity of cocaine use coincides with several changes in supply availability conditions. First, both source country cultivation of coca, the base crop used to produce cocaine, and estimated world production of cocaine have quadrupled since 1978 (NNICC Reports 1978-1988). According to straightforward economic reasoning, a shift to the right in the world cocaine supply will decrease prices at all levels of the production chain and increase the amount flowing into the U.S.. Increased availability and the resulting lower prices make the drug more affordable to lower income groups and adolescents, and thereby stimulate cocaine experimentation (Brower and Anglin 1987: 164-5). In turn, a rise in experimentation increases the potential for an increase in cocaine abuse and addiction. The greater the number of persons entering the pool of casual users, the larger the pool of potential addicts becomes, as a period of experimentation necessarily precedes heavier use

There are several reasons for the dramatic growth in supply. First, wages in the illicit coca trade are far above those in any other industry. While the average per capita income in Peru was approximately $1,100 in 1985 (Alvarez:1988: 8), it has been estimated that a family can earn upwards of $2,000 per year for harvesting dried coca leaves, or $10,000 by easily converting the yield to cocaine base (Carsisle 1989: 6). Second, many of the traditional industries in the Andean region such as mining have fallen on hard times leaving many dislocated workers in search of alternative incomes. Finally, past government policies such as implementing food price ceilings, and dispersing funds to favor urban development in the Andes at the preclusion of rural infrastructure development (Alvarez:1988: 9), have kept rural farmers wages below those of the rest of the region. If producing coca allows growers a larger net benefit than producing food, even after deducting food costs, they will be compelled to do so. Population growth in Chapare, Bolivia's major coca growing region, reflects the willingness of labor to revert to coca production, increasing six fold from 1981 to 1985, faster than any other region by far (Eastwood and Pollard 1987: 166).

Another aspect of the problem emphasizes the impact of drug use on health costs and society in general. For example, Cocaine related deaths have increased more than tenfold over the last decade. Cocaine related hospital emergencies increased fifteen fold during the same period (NNICC Reports 1978-1988). Among adolescents, cocaine is deemed to be a contributing factor in nearly 20 percent of drug related deaths within the 10-19 year old age group (Brower and Anglin 1987: 165). These dramatic trends also strike home the message that society is losing its most valuable resource --human potential-- at an exponential rate.

3. The Dynamic Hypothesis

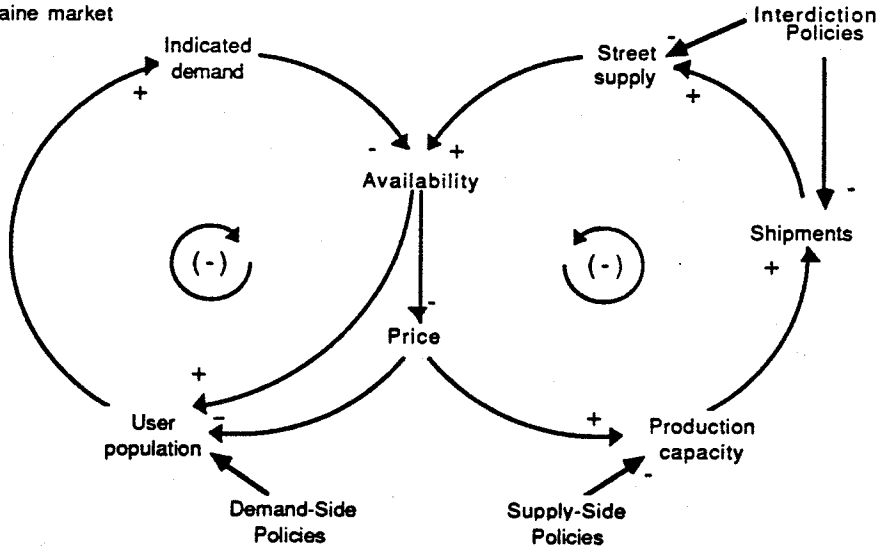
The drug problem involves a highly interconnected set of components. Therefore, little is gained by distinguishing between the supply and demand side of the problem from a policy standpoint, as policies aimed at either side of the economic equation affect the whole system. Failure to account for the tight bind between production and consumption may explain why past policies have had little success. Figure one presents a dynamic hypothesis of the predominant forces thought to be operating in the cocaine system. In essence, the prevailing

forces comprise two counteracting or negative feed back loops, that mutually adjust supply and demand when market conditions change. The left loop represents the demand side adjustment, while the right adjusts supply. Market behavior patterns depend on several factors, including the dimension of imbalance and the relative adjustment times of the demand and supply sides of the market. Delays and disequilibrium conditions are inherent in the adaption process as described below

To describe how the system behaves overtime, it is easiest to imagine the reaction of the market to an increase in our interdiction resources. In considering the overall market response to intervention policies, one begins from the assumption that supply and demand are in an approximate state of equilibrium. A shock to the market will upset this balance and give rise to a period in which the market adapts to the interruption in supply flow. During the adaption process there will be both short and long term implications as the production-distribution chain adjusts to the imbalance and effects market responses with differential time frames.

In the near term, a significant reduction in the inflow of cocaine to the U.S. would within a matter of months, begin reducing domestic availability through attrition. In this scenario, short term price effects start in the retail end of the distribution chain. As the ratio of supply to desired supply decreased, price will rise. This pressure is negative or stabilizing in nature, with price acting as a governing mechanism on demand. Within this short time frame, dealers and wholesalers will raise prices to maximize sales revenues in light of the tighter supply flow. In turn, we expect that demand as indicated by both sales and consumption rates, will begin to fall into line with the new supply level, as price limits accessibility to higher income groups and less elastic habits.

Figure 1. Basic dynamic structure thought to underlie policy resistance in the cocaine market



A second effect occurs in the short term as higher price levels will increase the domestic market's attractiveness and thereby stimulate increased import rates into the U.S.. The feedback relationship between inventory, price and availability described here is also stabilizing in nature. Price thus acts simultaneously to retard consumption and bring supply inventories up to meet the demand level being indicated by market price. In combination, these trends tend to counteract one another and stabilize the retail market quicker then either might alone. In the first instance, we find the desired effect one might expect from an interdiction policy, higher retail prices, and slowing consumption and sales rates. In the latter, we find a less obvious and often overlooked role of price in which it serves as an incentive to smugglers and wholesalers to increase importation rates.

Over a more moderate time period, sufficient interdiction policies will stimulate reactions by suppliers and producers beyond the retail market, as price effects ripple backward, and traffickers rush to exploit a more attractive U.S. market. In turn, suppliers inventories are depleted at an above average pace. Impacts may be delayed depending on the policy of suppliers to stockpile excess inventory to guard against such an event. Inevitably, a successful policy will force traffickers to increase orders to producers, bidding up price and exerting pressure to expand

processing capacity. Moreover, since shipping rate changes can occur quicker than changes in production, oftentimes capacity is over expanded to make up for shortages incurred during the period it takes producers to gear up for increased shipping rates (Mass 1980: 102). On the demand side, an interdiction policy which is sustained long enough to erode traffickers supply inventories, should be sufficient to make inroads into the size of the user population. However, it will likely be several months before there is any noticeable impact on consumption, and even longer before the user population is reduced through lower experimentation rates.

In the long term, the effects of sustained losses in the pipeline ultimately filter back to the primary production stage. This is the only stage where the losses can be replaced. In order to meet normal shipping rates plus seizures, cocaine production must expand, thereby increasing orders for coca, bidding up price, and setting off adjustments in rural coca economies. Since this sector is the farthest removed from our initial policy intervention, it will be the last affected by policies targeting the wholesale or retail sector. Adaption within the Andean agricultural sector is slow, first there is a lag between increased attractiveness of coca production and growers perception of changing conditions. Second, there are delays involved in planning and preparing land for cultivation, planting, crop maturation, harvesting, processing, and transportation to the next stage in the process.

4. Model Structure

In this section a simple system dynamics model of the cocaine industry is developed. The model was written using the STELLA software package and has been discussed in greater depth in a previous paper (Wuestman 1989), which is available from the author upon request. The overall structure of the model and the major endogenous variables are presented in figure 2 . Each sector contains structure and equations relating variables within the sectors bounds, as well as guidelines for interacting with other sectors. As shown, the model comprises three sectors: Andean agricultural production, Columbian cocaine production, and U.S. consumption. The Andean agricultural sector is further subdivided into food production, coca production and resource allocation sub sectors. The arrows connecting the sectors show the physical and information flows linking the processes of one sector to another. With the exception of the Andean population and agricultural resource base and the various policy levers, all variables and dynamics are treated endogenously in the model.

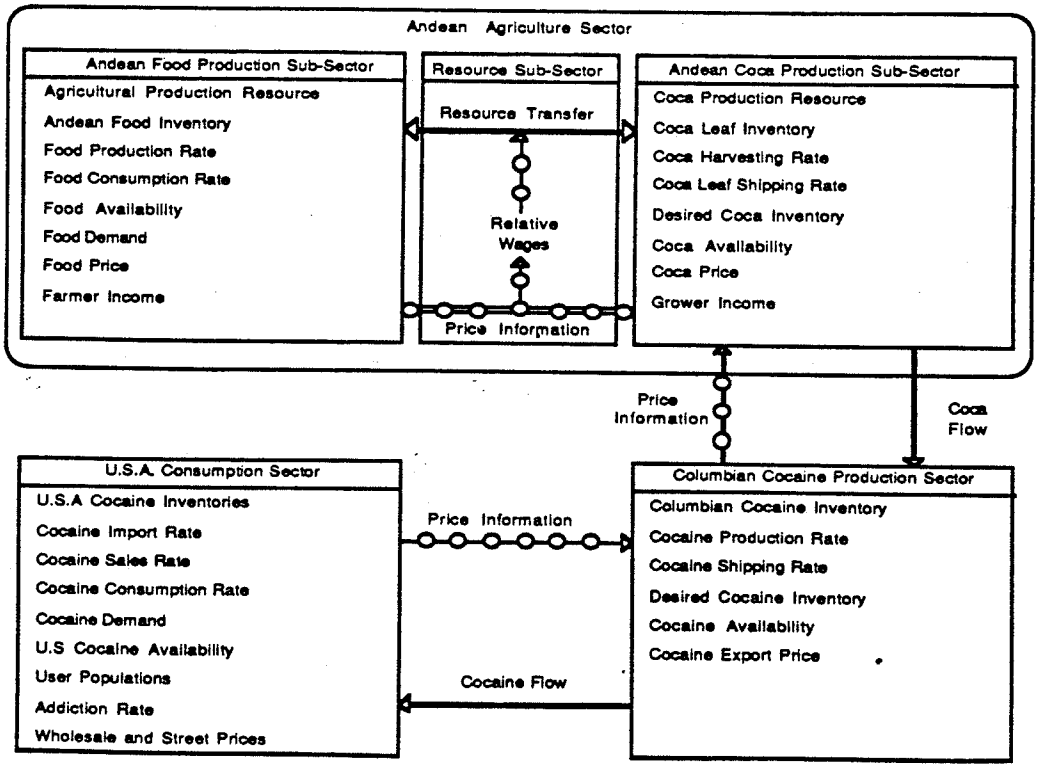


Figure 2. Aggregate Model Structure listing major endogenous variables by sector

The focus of the model presented here is on the dynamics that arise with intervention in the cocaine market. As stressed above, market interventions impact on both the supply and demand side of the equation, thus the model incorporates components of each. Figure 3 presents a simplified flow diagram of the model showing the levels, rates, and a generic view of the information flows comprising each sector. The four inventories connecting the coca production and U.S. consumption sectors represent the levels of supply in the production-distribution chain. The inventories are connected by a series of feedback loops which regulate the flow along the pipeline. The processes guiding each inventory flow are represented similarly, each containing an inventory, a goal or desired inventory, an inflow or production rate, and an outflow or consumption rate. The following sections briefly describe each sector.

4.1 *Source Country Agriculture and Resource Allocation*

This section describes the three sub-sectors of the Andean agricultural sector. At this stage of model development the agricultural sector remains highly aggregated. Although the source countries produce a number of agricultural products, the initial model restricts output to simply coca and food. The analysis focuses on two input factors, land and labor. For simplicity, the two factors are combined into a single unit of production, Agricultural Production Resource (APR). The agricultural resource base is finite, representing the total production possibility of the agricultural sector. Each unit comprising this level is equivalent to the output of one producer working two hectares of land.

Agricultural production is divided between a small coca production sub-sector and a comparatively larger food production component. There are several important determining factors in each. Coca Production Resource (CPR) measures the level of agricultural production units (APR) allocated to the coca sub-sector at any one time, and thus determines coca production. The stock rises or falls according to changes in market conditions. A second important stock is the coca inventory, which accumulates when production exceeds the shipping rate and falls when exports surpass production. In the food production sub-sector, Food Production Resource (FPR) measures the level of agricultural resource units and thereby determines food production. The other important level in this sub-sector is the Andean food inventory. Excess food production is accumulated in inventory and food is depleted through consumption. Both agricultural inventory levels provide important information in their respective sub-sectors for determining price, consumption, and wages.

The resource allocation sub-sector receives information from the production sectors and determines resource migration between the two components. The expansion or contraction of either sector is based on the relative magnitude of the prevailing farmer and coca grower wages. When wages are balanced resource allocation remains inert. When wages are unequal resources migrate toward the more attractive wage market. It is further assumed that transfer rates are limited. The maximum transfer rate is set at 5% annually, limiting coca sector expansion to an approximate doubling time of thirteen years. The structure of the market also serves to limit allocation. If one sector loses a significant amount of resource, price and wages will rise, increasing sector attractiveness, and drawing resource back into the market.

An additional factor that affects resource allocation is risk. Risk is associated with involvement in the dangerous and illicit coca trade, and thus deflates coca wages. In the simulated scenarios the risk factor is determined by the ratio of the government's eradication capacity to coca growers production capacity. The relationship represents the probability of a grower's crops being eradicated. Under initial conditions, it is assumed that farmer and risk adjusted coca wages are equal, and thereafter vary according to changes in the market.

4.2 *The Columbian Production Sector*

The Columbian cocaine production sector receives coca imports from the Andes and converts them into cocaine for export to the U.S. consumption sector. The sector operates similarly to the other four supply inventories along the pipeline. The major determining stock in the sector is the cocaine inventory, which accumulates excess production and is depleted by both export and interdiction rates. Export (consumption) rate averaged over a period determines the desired inventory and sets the goal for the sector.

Discrepancy between actual and desired inventory is captured by the availability ratio, and is a factor in determining price. When availability is low, price rises, and conversely when high, price falls . Price movement is then relayed in two directions simultaneously, both toward the primary production phase, setting the stage for future production, and toward the consumption sector determining the amount that wholesalers (consumers) are willing to purchase. The adjustment process contains two stabilizing loops centered on price, one which regulates inflow to the sector, and another which governs consumption.

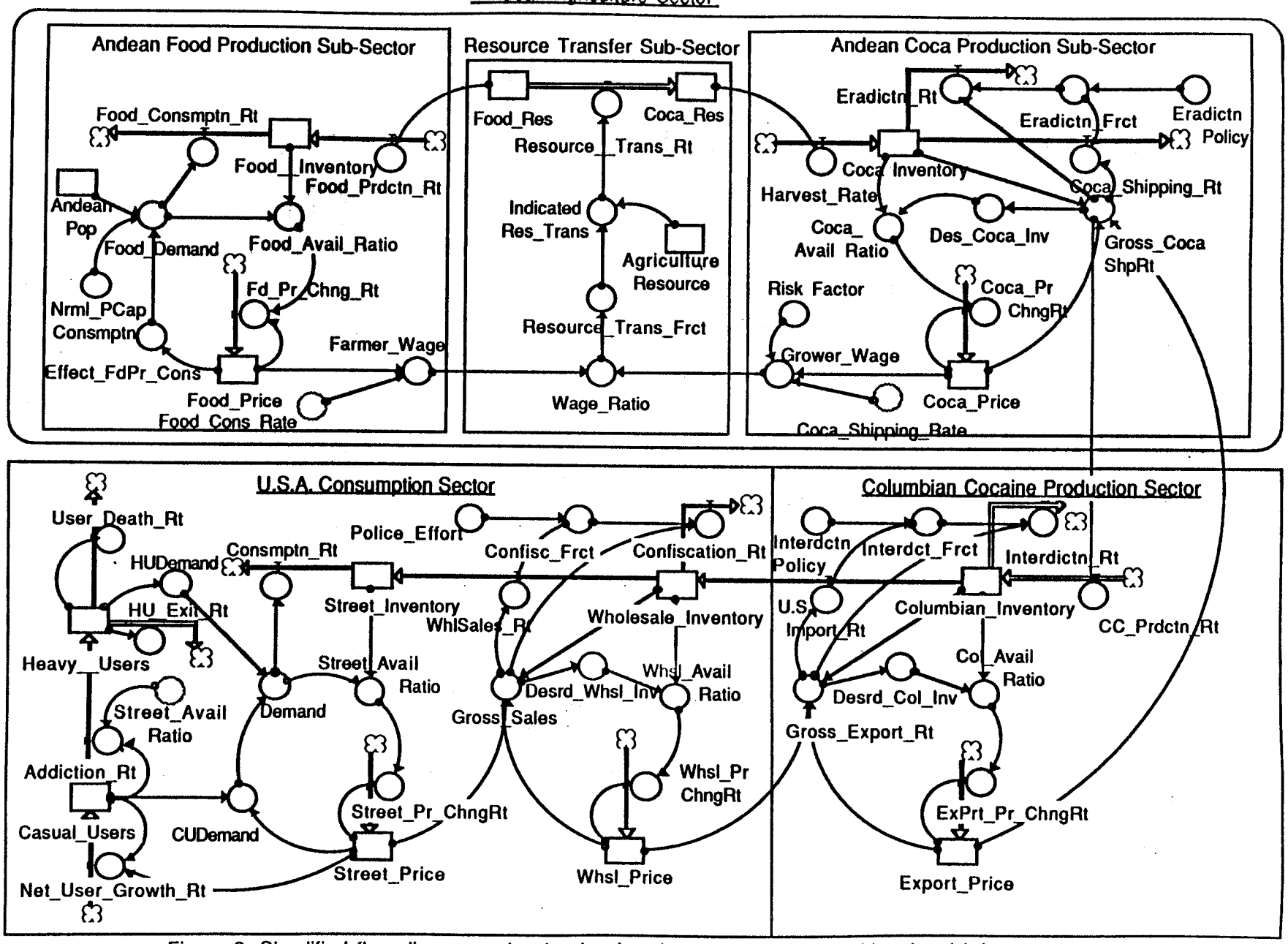


Figure 3. Simplified flow diagram: showing level and rate structure with abbreviated information flows

4.3 *The U.S. Consumption Sector*

Supply in the U.S. consumption sector is represented by two inventories, wholesale and street. The wholesale inventory connects the U.S to the international pipeline. It is fed by an import rate and depleted by sales. The street inventory is the final point of distribution and is fed by wholesales and depleted through final consumption by the user population. Demand determination is slightly more complicated in the final retail sector because it can be affected by price as well as changes in the size and composition of the user population. Users are composed of several categories ranging from those who try cocaine only once during the year to those that use several times a day. To observe how policies impact heavy users, as opposed to light and moderate users, the population is subdivided into two categories. The heavy use category contains all those who use at least once a month, while casual users comprise all those that use at least once during the year but less then once a month.

Growth of these two populations is treated within the model. There are two facets of user population growth, those which affect experimentation and those which impact the addiction rate. Price and cocaine availability are important variables in determining the growth of both groups. A shift in the supply balance causes price movement which in turn affects the probability that potential users will experiment with cocaine. When price is high the growth rate of casual users declines, and when low, the pool increases. The growth rate of both groups has a self-reinforcing characteristic commonly known as the " peer group effect". As the population in either group grows, growth rates are allowed to increase more rapidly. Similar to the spread of an epidemic, one person can"turn on" and infect several others with the infliction, thus generating exponential growth. Growth occurs in the heavy use category as a proportion of casual users are drawn into the heavy use pool each year. The fraction which become addicted varies with market availability conditions. Periods of high availability facilitate addiction, as low price and ease in obtaining the drug spur increased use.

The user population can be drawn down by a death rate, or through heavy users exiting the system as they grow tired of the lifestyle. Like user growth, the death rate involves a proportionate relationship with the size of the heavy user population. If the heavy user pool grows the death rate parallels its growth by a constant fraction and conversely, if the number of users fall so too will will user deaths.

4.4 *Price and Consumption*

Consistent with classical economics price has a negative impact on demand. Given the illegal status of the drug and problems limiting availability for conducting controlled experiments, research has made very little progress toward providing a dependable estimate. For this analysis, a relatively inelastic -.25 is assumed. Consumption also varies across different user groups, hence, independent habits are used for heavy and casual use. To account for different frequency of use patterns within each population, average habits were adopted. Finally, heavy user habits differ in that they are assumed to be inelastic to price.

5. Model Behavior

This section examines the dynamic behavior of the simulation model. The model has been tested using various partial model tests and alternate scenarios (Wuestman 1990). The simulation results are not meant to be accurate forecasts of future cocaine supply or use but to help clarify understanding about the cocaine problem and the implications of implementing remedial policies. For comparison purposes, all the simulation were conducted in similar fashion. Each simulation begins with approximately 5 million users consuming 60 metric tons of cocaine per year. The system is initialized in a moderate growth phase with users increasing 3% annually. The market was then disturbed with one of the following interventions: 1) stepping down supply at different points along the pipeline.(eradication targets coca supply, interdiction restricts cocaine import, and confiscation depletes street availability); 2) reducing the user population through preventive education and rehabilitating heavy users; 3) enhancing source country food production.

5.1 *Base Run: Non-Intervention Scenario*

Figure 5a shows the simulation results using selected demand-side variables of the base run. Figure 5b reveals the behavior of supply-side variables of the base run. In the absence of intervention, the casual user population grows for the first five years of the run pulling consumption along with it and adding to the pool of

heavy users. During the spurt, U.S. imports and other supply indicators remain stable, allowing the market to tighten under growing demand, as evidenced by a 20% drop in availability. The combination of tighter availability and high prices that accompany such a scenario lead first to a drop in consumption, and subsequently, to a decline in the casual user pool. Note that it takes several years for price to exact a noticeable impact on casual users.

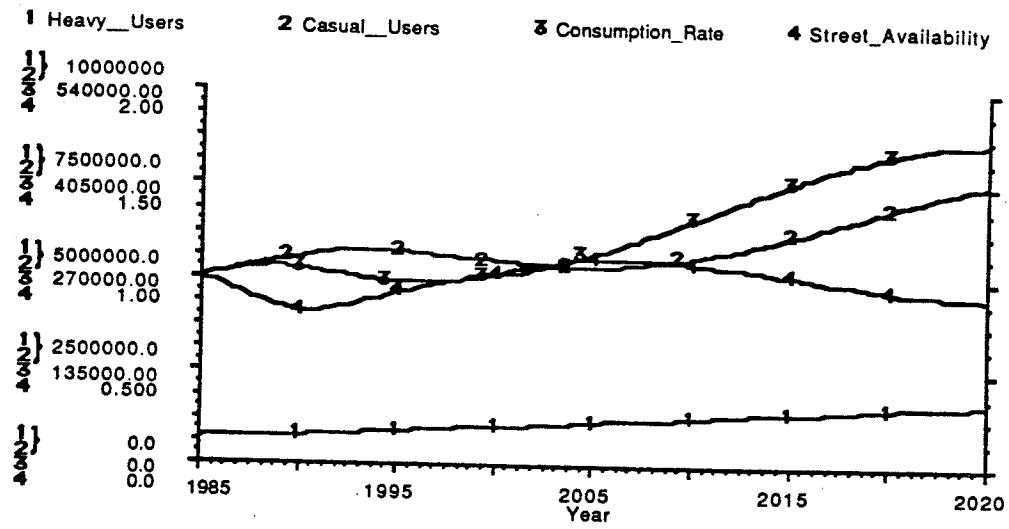


Figure 5a: showing behavior of demand indicators in a base run non-intervention scenario

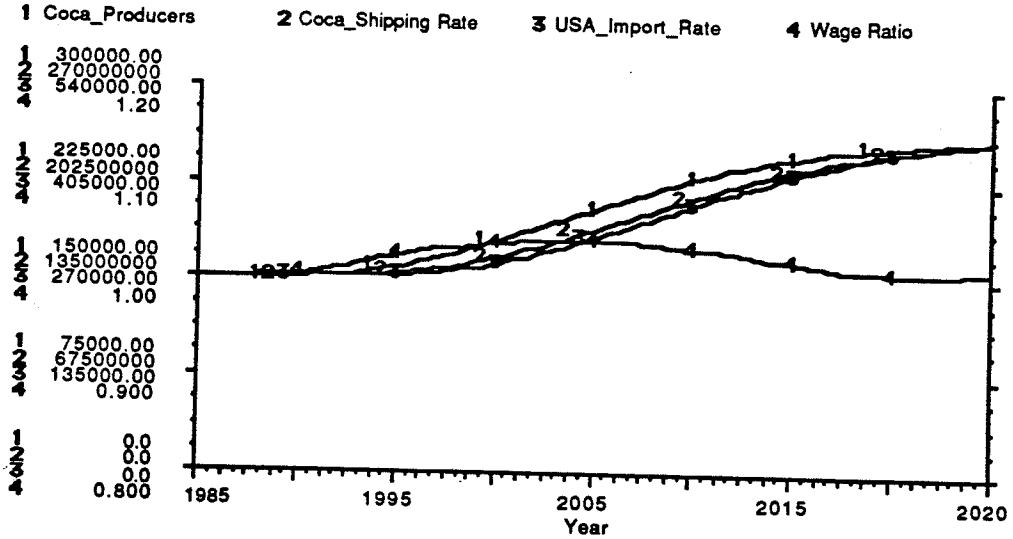


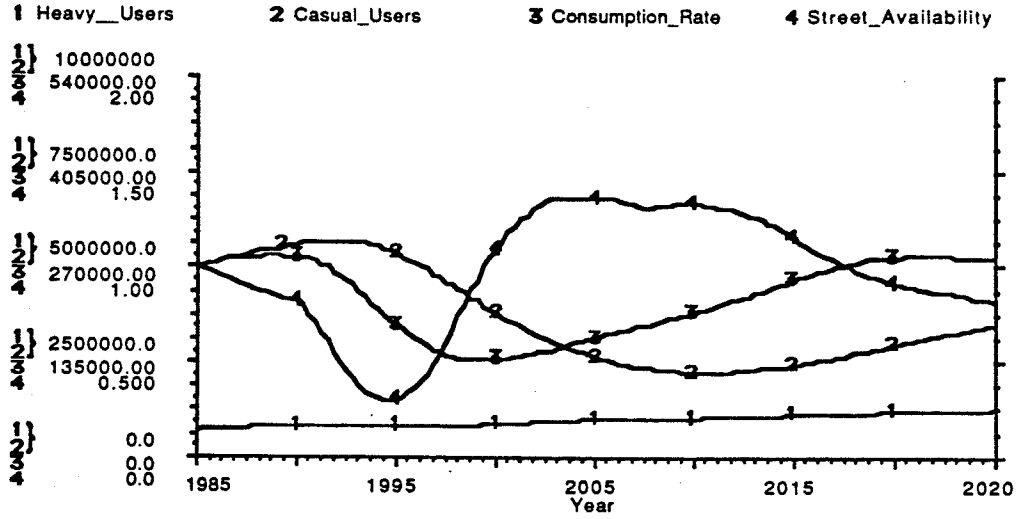
Figure 5b: showing behavior of supply indicators in a base run non-intervention scenario

During the next fifteen years, consumption goes from a steady state into a second growth phase. Growth is fueled by the delayed response of expansion on the supply side to the high price and low availability of the preceding period. Years 15-20 reveal a change in the wage ratio at the commodity level; evidence that the demand signal has reached the far end of the production chain, raising coca wages and attracting resource into coca production. Also, note that heavy users have grown steadily over the period showing that the slight decline in the proportionally larger casual user population had little impact on the flow into this population.

The final fifteen years of the run are characterized by a dramatic growth in both the demand and supply side of the market. The increased supply flow from the tenth year on, as indicated by the import rate, fuels a resurgence in casual user growth. During the final stage, the absence of any downturn in consumption indicates that the system adapts by ordering sufficient production capacity to satisfy a much larger user population.

5.2 *Multi-Supply Policy Scenario*

The behavior of the model to the concurrent application of three supply side policies is shown below (Figures 6a-6b). Policy one is a constant eradication of 10% of coca harvests needed to meet initial demand. Policy two is an interdiction of 15% of the base run import rate. Policy three is a 10% confiscation of initial retail inventory. All total, an interdiction rate equal to 35% of initial supply is implemented in year five and maintained throughout the simulation.



Figures 6a: showing behavior of demand indicators under a multi-supply policy scenario

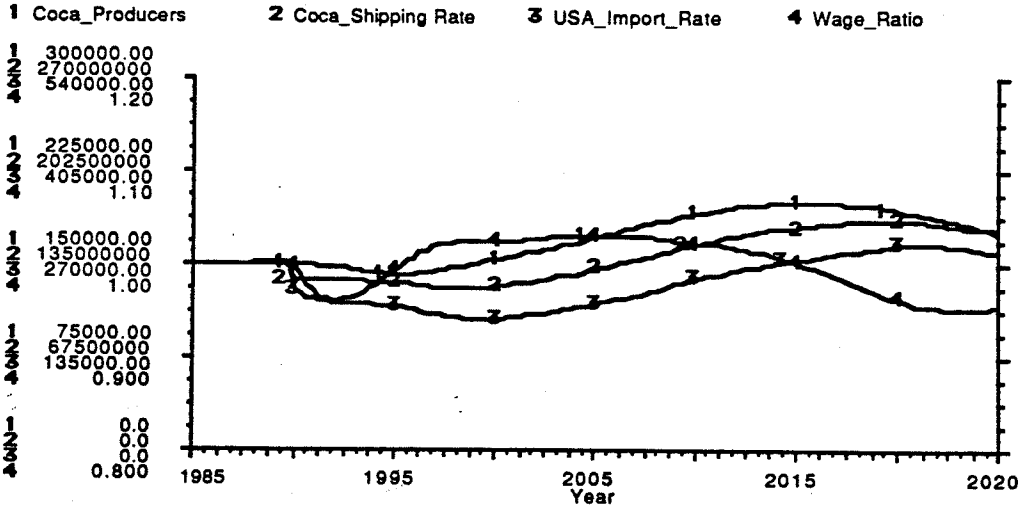


Figure 6b: showing behavior of supply indicators under a multi-supply policy scenario

The first five years of the simulation are identical to those of the earlier runs. As the indicators reveal, there is growth in both users and consumption, paralleled by falling availability. Shortly after program implementation in 1990, all demand indicators with the exception of heavy users show dramatic decline. Reducing this group requires substantial time, as gains must be made by first lowering the proportionately larger population of casual users from which heavy users flow, or by treating addiction through more direct means.

Between 1995-2005, the program's secondary effects become evident as availability bottoms out and begins an upward swing. Despite a 35% contraction of initial supply, availability comes surging back from 75% below initial conditions to 30% above, over the ten year span. This phenomenon may seem surprising, however, contradictory

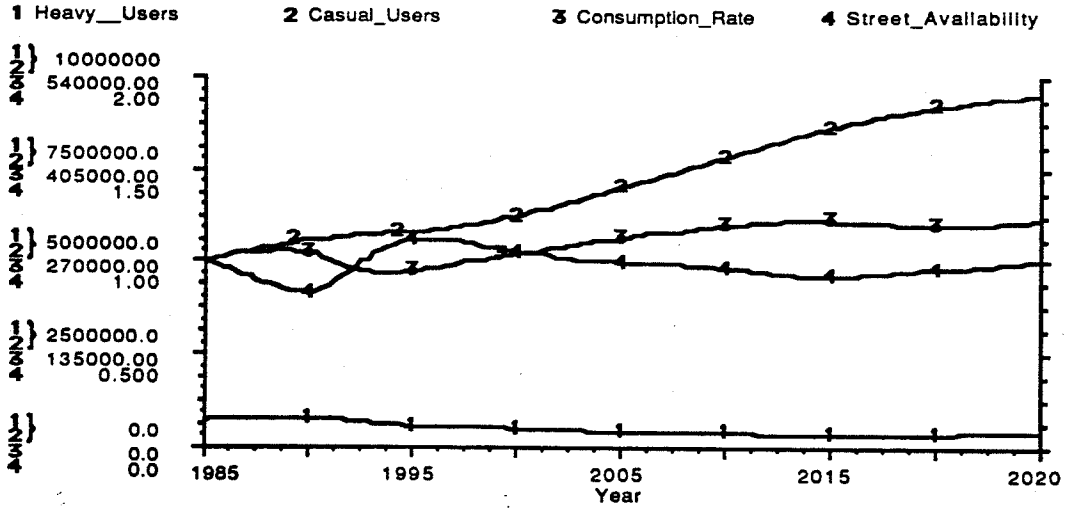
behavior is explained as the result of a decline in consumption. Although cocaine imports have been substantially reduced, low availability has brought high price, suppressing consumption and in turn, causing the market to actually be over supplied because less supply is desired. The upsurge in availability results as consumption slows and expanded supply production capacity enables an increase in imports that eventually overrides interdiction capability. As shown, there is a significant delay on the supply side of the market before coca production is able to expand exports. In addition to a information lags throughout the market, eradication of capacity (crops) hinders production activities. Approximately three years is required to replace the productivity of a mature coca bush.

The second half of the simulation shows the compensating tendency of the market system. As availability rises, prices fall, and consumption shows a resurgence. Expanded supply side production capacity allows both sides of the market to continue growing throughout the remainder of the run.

5.3 *Multi-Demand Policy Scenario*

Many critics of current interdiction policies argue that the demand side of the market is the key to alleviating the cocaine problem. Several simulations were conducted stepping down the rate of flow into the casual user pool, the aim of preventive education, and stepping up the outflow from the heavy user population, the goal of a successful rehabilitation policy. Figures 7a-b show the results of a combined effort of these two demand reduction initiatives using selected indicators of supply and demand behavior.

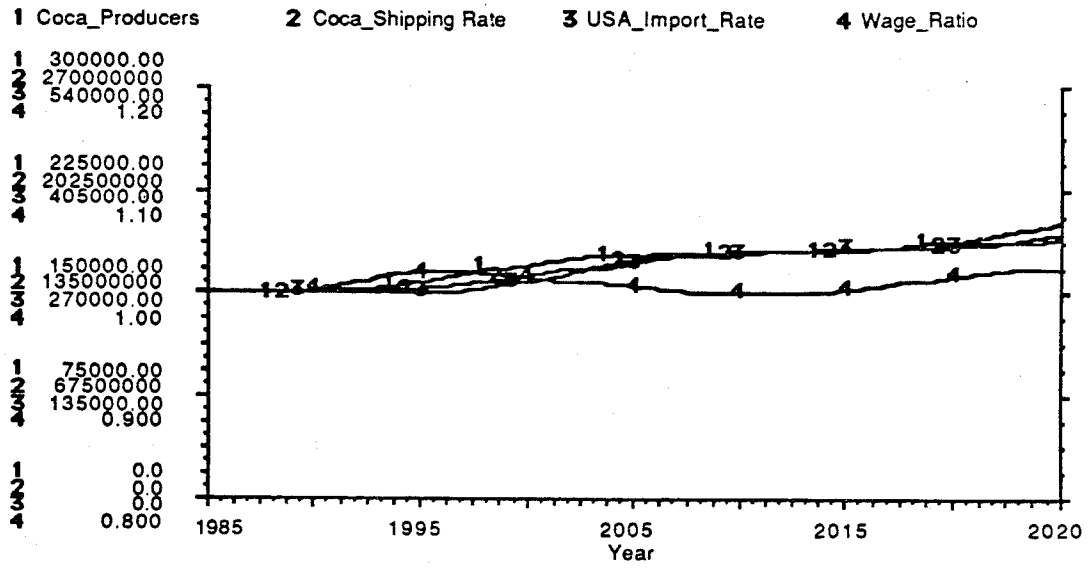
During the five years following implementation, behavior takes the form of a slow moderate downturn in consumption, paralleled by an opposite movement in availability conditions. The difference in short term behavior from the previous scenario, is linked to the nature of the intervention. In this scenario, reduced consumption is directly related to less users, and in contrast to the previous run, results are not dependent on supply shortages moving through the pipeline and shifting price. Under cutting demand avoids the high price scenarios associated with interdiction and supply shortages, and thus the influence of price pressure on supply production is negated.



Figures 7a: showing behavior of demand indicators under the multi-demand policy scenario

Over the second third of the simulation, consumption shows a rate of incline due to an increase in casual user growth rates (Figure 7a). The rise in casual use may seem surprising in light of the implementation of a preventive education program. The growth, however, is explainable as a side effect of reducing the number of heavy users. Since this group consumes a large portion of supply, a glut is created by depleting their numbers. High availability, accordingly, depresses price and stimulates experimentation and casual use.

In the final third of the simulation growth of the casual user pool begins to level off at a much higher population level. Logic dictates that there will inevitably be a resurgence in heavy use, as a proportion of the now larger casual use population fuels the addiction rate. In fact, the very last years of the run show both consumption and production indicators rising. A sufficiently large supply inflow will permit both groups to grow simultaneously. In solving one aspect of the problem a tradeoff is created that allows the problem to return in an amplified state.



Figures 7b: showing behavior of supply indicators under a multi-demand policy scenario

5.4 *Alternate Policy Scenarios*

Several policy options were tested independently as well as combined into policy sets. In the majority of the combination runs explored with the model the rehabilitation and preventive education policies were teamed with a supply initiative. The long term results taken from year 40 of the simulated time horizon, are summarized in Table 1 below. The base run with no intervention is used as an index to which all subsequent runs are referred. A one point deviation on the table equals a one percent change from the initial simulation result.

In policy set A, a 15% interdiction was teamed with the demand program. The two policies tended to counteract one another. While interdiction attempts to achieve the aim of tightening the market and raising prices, rehabilitation acts to free up supply by depleting heavy users. Comparing results with those of the multi-demand policy it is clear that the addition of the interdiction program had little impact. The hitch in the policy lies in the nature of supply intervention. When supply seizures target the supply in the pipeline price effects move in two directions simultaneously. Heading toward the commodity stage price has a domino effect on the attractiveness of each sector. In order, seizures will first drive up export price, and thereby stimulate paste and coca production. Before slow working demand tactics can effectively suppress consumption, supply line losses are being replaced. Moreover, as price moves to suppress consumption, excess supply supplements increased shipments and creates an oversupply in the retail market. During the period of of high availability that follows, policy benefits are quickly lost as price entices new users into the market.

In policy set B, a moderate eradication policy is used as the supply side tactic. The simulation assumes the same intensity for the policy as in the individual runs summarized in Table 1. The benefit of the policy can be traced to the direct impact it has on coca wages. While other supply side programs tighten the market and raise prices, new supply is always forthcoming. Eradication policy hits the pipeline where it hurts the worst by destroying capacity which can only be replaced after lengthy delays. The results suggest that the policy is a good supplement to a demand regime. The destruction of production capacity (crops), which take several years to mature, insures low availability and high prices for an extended period. By halting the pipeline at the primary production point, other sectors are also halted. A subsequent period of low supply then allows demand tactics to work on user populations concurrently with high price. Overall, the program was the one of the most successful policy sets at lowering both consumption and production activities simultaneously. The program was also one of only two that were able to able to reduce heavy use without encountering offsetting gains in the casual user population.

Table 1.

Relative Magnitude of Market Indicators *

Policy Intervention	Heavy Users	Casual Users	Total Consumption	Cocaine Production	Coca Production	Resource In Coca	Food Production
Base run: no intervention	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1. Coca Eradication							
Moderate (10%/year)	0.83	0.52	0.67	0.67	0.67	0.73	1.01
Strong (20%/year)	0.61	0.07	0.23	0.22	0.21	0.29	1.04
2. Interdiction Policy							
Moderate (15%/year)	0.91	0.92	0.90	0.88	0.95	0.92	1.00
Strong (25%/year)	0.86	0.86	0.84	0.79	0.92	0.88	1.00
3. Police Seizure	0.95	0.96	0.94	0.98	0.97	0.95	1.00
4. Preventive Education	0.99	0.97	0.99	0.99	0.98	0.98	1.02
5. Rehabilitation/Treatmant	0.25	1.31	0.74	0.76	0.78	0.81	1.01
6. Agric. product. enhancement	0.96	0.86	0.90	0.90	0.91	0.91	1.01
7. Multi-Supply Policy	0.72	0.46	0.61	0.61	0.68	0.67	1.02
8. Multi-Demand Policy	0.24	1.26	0.71	0.73	0.74	0.77	1.01
9. Policy set A	0.22	1.23	0.68	0.69	0.78	0.77	1.01
10. Policy set B	0.19	0.88	0.48	0.49	0.49	0.54	1.02
11. Policy set C	0.22	1.25	0.69	0.75	0.76	0.77	1.01
12. Policy set D	0.23	1.18	0.66	0.68	0.69	0.72	1.12
13. Policy set E	0.79	0.38	0.56	0.57	0.56	0.61	1.12

Multi-Supply = eradication + interdiction + police confiscation

* Indicators are ratios of the base run simulation

Multi-Demand = rehabilitation + preventive education

Policy set A = interdiction + rehabilitation + preventive education

Policy set B = eradication + rehabilitation + preventive education

Policy set C = confiscation + rehabilitation + preventive education

Policy set D = farmer productivity enhancement + rehabilitation + preventive education

Policy set E = farmer productivity enhancement + eradication + preventive education

Policy set C combines police confiscation with demand reduction. The program suffers the counteracting forces of rehabilitation and preventive education policies similar to the behavior shown in the multi-demand simulation. While the policy successfully reduces the heavy user population 80% by the end of the run, casual users show a 25% increase over the base run scenario. On the supply side, the confiscation program proves insufficient to control the rise in availability that accompanies reduced heavy user consumption. Lacking a strong supply country initiative as well, the strategy also allows the shifting of resources into coca, and thus is overwhelmed by an enlarged supply flow drawn by the growth trend in casual use. Although consumption is ultimately reduced 30% over the base run, other combinations proved more effective in suppressing both production and consumption rates.

Policy set D teams the demand regime with a productivity enhancement of Andean food production. The additional policy is simulated by stepping up annual farmer productivity and hence, initial farmer wages by 10%. As intended, the policy meets with moderate success in suppressing production indicators by drawing resource away from coca production. However, the program also encounters the offsetting influences of the demand reduction policies and permits an 18% gain of casual use over the base run scenario. The strength of the program lies in its beneficial effects on farmer wages and source country food production. Benefits on the demand side will only be realized in the long term as the structure of the Andean agricultural sector is slowly altered.

Of all the policy sets simulated, combination E is strikingly superior on several accounts. The strategy

applies both the incentive of higher farmer wages and the disincentives of eradication to the Andean agricultural market, simultaneously. On the demand side, rehabilitation is set aside while preventive education remains. The success of the strategy relies on a combination of the long term impact on users, and a simultaneous reduction of resource allocated to coca production. As the indicators illustrate, the program depresses both sides of the market. Although heavy users are not reduced to the extent of some of the other combinations, the largest reduction of the casual use population of all policy sets is achieved. The implication of the reduction is that future growth of the heavy user pool will be a trickle as compared to other scenarios. A second noteworthy result, is the effect of the policy on Andean food production which at the end of the simulation exhibits a 13% rise above the base run simulation. While the accomplishment does not imply any immediate tangible gains in the U.S., it translates into a source of substitute employment for those involved in producing coca. The alternative may hold the key to source countries permitting the effective destruction of coca production capacity. Whether such a policy is actually implementable is a relevant question currently being raised by experts in the area. The simulation of the policy supports the notion that the proposal should be given serious consideration.

6. Preliminary Results and Implications for Further Study

Two general purposes are pursued in constructing and analyzing the preliminary system dynamics model of this study. The first purpose is to draw attention to some of the complex forces present on both sides of the economic equation that interact to create the cocaine problem's persistent nature. In particular, the model develops a dynamic hypothesis that policy resistance is grounded in the feed back structure comprising the market. The base run scenario supports the dynamic hypothesis that the problem is attributable to both sides of the economic equation. When the model is initialized in a user growth pattern, endogenous market pressures passed from retail through the distribution chain act to stimulate expansion in the coca production sector. When demand is reduced below production levels, high supply and the accompanying price effects are sufficient to encourage growth in the user population, and thus stimulate the demand side of the market.

The simulation model also identifies several key sensitive features in the cocaine system. The self perpetuating characteristic associated with growth of the user population, raises important questions about the extent of price in suppressing user growth rates and the type of policies that can help break the peer group pressures that are typical of rapidly expanding popularity with certain drugs. A second sensitive structure identified by the model focuses on the migration of resources within the rural Andean economy. The discrepancy between coca and other agricultural wages provides one explanation for the dramatic increase in recent coca production trends. Intervention at this important decision point may therefore provide a key policy lever for developing a strategy which directs resources away from coca production rather than stimulating expansion.

The second aim of the study focuses on the implementation effects of several commonly proposed alternatives in a dynamic framework. In general, simulation results of the preliminary model support a popular recommendation in current literature for a shift in the emphasis on supply side programs toward a more comprehensive approach. In searching for a strategy that maintained long term market suppression, the best results were achieved in simulations using a balance between demand and supply track programs. Preliminary findings suggest supply intervention tactics that raise price and reduce consumption in the short term are only useful to keep the problem from becoming worse. Of the available options, eradication and productivity enhancement policies were superior to interdiction as they tended to induce resources away from coca production whereas interdiction tends to foster expansion by maintaining high market prices. However, other initiatives are necessary to address the deeper structural elements of the problem. These types of policies would include the incentives which undermine demand and negate incentives that drive resources into the illicit trade. In source countries, this may translate into providing rural laborers with comparable forms of alternative legal income. Domestically, an effective strategy may require implementing several policy levers simultaneously. As discussed above, there are several different classes of users that behave differently and thus, it is likely that it will be necessary to identify and treat them independently.

The study also shows that long and short term policy implications can differ greatly due to compensating responses that interventions at one point in the system tend to foster in others. This point is most clearly illustrated in the policy scenarios involving interdiction policies. In the short term, price effects acting within the retail sector serve to depress consumption and growth of the user population. Conversely, in the long term behavior is dominated by the response of source country production sectors as price impacts serve to expand cocaine production which lowers price, and ultimately fuels a resurgence in experimentation and the user population. Moreover, the results reveal that more of a seemingly good policy is not always better. Initiatives that increased the intensity of

the moderate interdiction and eradication policies encountered diminishing marginal returns and therefore were less effective than broadening the base of the attack.

The simulated scenarios also suggest where the model can benefit from expansion and further research. First, the success of the productivity enhancement and eradication policies imply that expansion on the supply side of the model warrants the development of a multi-economy framework, with the addition of an industrial goods sector. Such a framework would be more appropriate for simulating alternative income generating strategies. Second, there would also be benefits to more accurate estimates of the price elasticity for labor migration between various labor markets for such a study. Also, questions regarding the negative effects of the coca boom as a contributing factor to the economic and political instability of the Andean source countries suggest expanding model boundaries to include government accounting and foreign exchange sectors. The astronomical inflation rates in these countries may be associated with the rapid influx of coca dollars to the region.

For simplicity, the initial model does not address the sociological or psychological aspects of drug use. Hence, the model can be modified to treat this aspect of the problems. Further research to identify determinants and risk factors associated with drug abuse are necessary prerequisites for developing an effective demand reduction strategy. Also, policy levers are exogenous in this initial version of the model. Community and government and actions can therefore be incorporated into the feed back structure of the model in future phases. Moreover, the model does not exhaust the list of remedial policies. Several policies were chosen for testing in the initial stages of development. Further model refinement can add options to the list such as decriminalization, legalization, drug testing and numerous others. To meet this purpose, the user population structure represented in the model of this study can be disaggregated to provide a more detailed description of user dynamics.

Finally, it should be noted that the model depicts the cocaine industry as a commodity structure, comprised of a series of interrelated markets, with availability and pricing mechanism determining market clearing rates. Therefore, results and generalizations are limited to the extent that the industry is vertically integrated. Continued research into the nature of the organizational structure of the industry is needed to supplement the information that is available in this area.

7. Conclusions

This paper presented a preliminary system dynamics model for analyzing the persistent nature of the cocaine problem. The simulation model described the commodity structure of the cocaine industry from production to final consumption. Using this framework the paper examined the implementation effects of several remedial policies.

The model produced several interesting findings. First, alternate scenario tests of the initial model showed why there is a need for a more comprehensive approach to the cocaine problem. Experimentation with the model identified several key structures and behavior modes that merit future consideration in developing strategies and researching the problem. In particular, the model illustrated how many of the currently proposed policies produce results that tend to counteract one another. Simulations also illustrated how interdiction policies can have attractive short term effects but undesirable long term impacts by fostering expansion in drug production capacity and user population.

The study also identifies several areas of promising future development and applications for the model. Further refinement, may prove useful in examining problems particular to source countries. For example the model can be used to experiment with alternative income generating or development scenarios. In addition, the model may prove useful for examining policy options other than those selected for this study. In a different mode, the model may prove useful for subsequent research which examines the different roles of major market players such as cartels and interdiction forces. This line of research would focus on the decision making aspect of developing strategies in a dynamic market in which key players are forced to adapt to one another.

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