Dynamics of the illicit drug market in Italy

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SUBMITTED TO THE MIT SLOAN SCHOOL OF MANAGEMENT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN MANAGEMENT STUDIES
AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JUNE 2016

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Submitted to MIT Sloan School of Management on May 6, 2016 in Partial fulfillment of the requirements for the Degree of Master of Science in Management Studies.

Abstract

Alongside street crime, a high prevalence of illicit drug consumption in the population represents a great source of funding for organized crime, and this is especially true in Italy, where the main criminal organizations control almost all the imports of cocaine and heroin: as a consequence, it is of the utmost importance that the policymakers take decisive and effective actions against the prevalence of illicit drugs in the country. However, the fact that the data about the prevalence of consumption is self-reported by substance users might represent an obstacle to an objective planning and evaluation of repressive policies: it is well documented how the reporting rate is lower than the actual prevalence in the population. This research attempt to address this issue by modeling a structure of the Italian market for the two main heavy drugs in the country (cocaine and heroin), using the tools provided by System Dynamics, specifically to analyze the effects of the introduction of the law n.49/2006.

The results presented by the model – and consistent with the real data – show that the actual prevalence in the population is increasingly different from the reported one following the implementation of the law. This result implies the necessity for policy makers to adopt more accurate tools for the evaluation of past and proposed policies, in order to be able to estimate the dynamics involved in the complex and little known market of illicit substances.

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Acknowledgment

I would like to thank my parents, my brother and my entire family: my whole academic career, from high school to the completion of this thesis, could not have been possible without you, your support and encouragement.

Gabriele Martegiani
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1. Introduction

In the broader context of fighting the organized crime, one simply cannot avoid talking about the illegal drug traffic. Especially when considering Italy, illicit drug trafficking – most of which, in terms of revenues, is represented by cocaine and marijuana in their various forms – replenishes the organized crime's pockets with money which will be eventually spent in corruption and money-laundering activities, with the associated negative effects on the “healthy” legal economy. If we were to consider as well the cost currently associated with the fight of this phenomenon, with tribunals all over the country overwhelmed with trials against minor drug dealers, more than 24,000 incarcerations a year for drug related felonies and their associated incarceration expense (above €1 Billion per year) the toll would significantly rise. On a smaller scale – albeit not less important – when considering the negative effects of high prevalence of illicit drugs, it is also necessary to keep in mind the well documented causal link between street crime and drug addiction (Ousey & Lee, 2016). For all these reasons, a clear and meaningful estimate of the national prevalence of the main and most addictive types of illegal drugs it if of the utmost importance to the law enforcement agencies both in Italy and around the world.

The first issue with these estimates, however, is how they are computed: since it is an illegal business there are no official statistics or records of its size both in terms of revenues nor quantity, and – currently – most of the drug contrast initiatives are modeled based on the results of the self reported prevalence in national surveys. These numbers are often misrepresenting the actual population of addicts in the country and this is especially true when particularly repressive drug contrast policies are introduced. Building on the assumption that because of these specific policies, aiming at increasing the legal punishment – and therefore the fear – of illicit drug consumption, users might influence the self reporting rate, biasing the recorded results of the policy itself, this research will focus onto building a model that could represent the actual status of the drug-abusing population in Italy following the now abolished law 49/2006.

The case of law n.49/2006

consequences of both possession and trade of illegal psychotropic substances and introduced the equivalence between the so called “light” drugs (cannabis, marijuana, etc.) and “heavy drugs”. Since its inception the law was highly criticized because it contradicts the results of the 1993 referendum on drug consumption, and it was in fact deemed unconstitutional by the Italian constitutional court and abolished in 2014 (La Repubblica, 12/02/2014).

Throughout 8 years, such law impacted significantly to the national judiciary and penitentiary system and, as reported in the periodic pamphlet “Il quarto libro bianco sulla legge Fini-Giovanardi” (Magistratura Democratica, 2013) as of 2012 some 120,000 people were arrested because of it, and as much as one third of the entire inmates in the country were jailed because of drug-related crimes, most of which linked to excessive personal consumption or small dealing: even the detention of a very limited quantity of marijuana was heavily punished, to the point that – as soon as the law was abrogated – some newspapers published guidelines on how to request a condemn reduction for drug possession crimes (VICE, 19/15/2014). On the other hand, the reported rates of prevalence of drug addiction in the country have diminished: after a period of undoubted growth of consumption between 2000 and 2005, as shown in figure 1 and 2, both the reported prevalence of Heroin and Cocaine decreased after the promulgation of law n.49/2006.

![Reported Prevalence of Past Month Users of Cocaine](image)

Figure 1 - Reported Prevalence of Past Month Users of Cocaine

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*a Note that the entire prison population in Italy is only 66,000 people.*
Without entering in the decades-long discussion concerning the legalization or the contrast of psychotropic substances, this research intends to provide an instrument that, taking into account the dynamic effects of changes in policies, seizures and other market and perception dynamics, offers an unbiased estimate of the actual prevalence of consumption of the two more popular heavy drugs in the country, i.e. cocaine and heroin. The implementation and successive abrogation of the law n.49/2016 discussed above represents a unique opportunity to calibrate and compare the model with the actual results from the reported cases of cocaine and heroin addiction in the country, and based on the results it will be interesting to investigate what the model suggests about the future, and what the reported and actual prevalence will be once the law is abrogated and its effects dissipated.

Reasons for a two-drug market analysis

Among the different reasons to choose a two-substances analysis for this specific model, it is worth pointing out that cocaine and heroin are by far the two major sources of revenue for the organized crime and particularly the main three Italian mafias “Cosa Nostra”, “’Ndragheta” and “Camorra” (note that whereas marijuana sales total an higher amount in revenue, its trade is dominated by smaller criminal groups (VICE, 05/11/2011)). Secondly, the first insights (La Repubblica 16/03/2016) of this year result of the ESPAD survey (European School Survey on Project of Alcohol and Other Drugs) are reporting an alarming increase in the heroin consumption in the 15-19 years old population, peaking at an incredible 2% of 15 years old.

For the sake of simplicity with Cocaine and Heroin I indicate Cocaine Powder and White Heroin, due to the fact that the prevalence of other qualities of both drugs - such as Crack Cocaine and Brown or Black Heroin - is negligible in Italy.
males consuming heroin in the 30 days before the survey: heroin being highly addictive, this increase in popularity among high school students will probably result in a future higher prevalence in the overall population.

Furthermore on this issue, and more specifically in the broader context of drug abuse, polyconsumption – i.e. the consumption and/or addiction to two or more substances at the same time - is currently the first cause of death by overdose (de Oliveira, Alberghini, dos Santos, & de Andrade, 2013), with the combination of cocaine and heroin (the so called “Speedball”) gaining again popularity in recent years (La Repubblica, 11/04/2016): whereas this study does not intend to specifically analyze the issue of polyconsumption, it might be useful to lay ground to future research on this topic by modeling how the reporting rate of the population is affected by public policy and other market forces.

A note on methodology: why using System Dynamics for drug market modeling?
In a complex environment like our modern society is, the evaluation and optimization of public policies increasingly demand for a more accurate, simple and dynamic forms of modeling, a need that might well be satisfied by the tools offered by system dynamics. A modeling effort in this direction might in fact benefit the definition of drug control policies in to ways: first, with the qualitative process of modeling itself and secondly with a quantified computer simulation. Researchers have yet raised concerns about the usefulness of a quantified simulation of the modeling resulting from a a priori modeling effort (Coyle, 2000), stating that most value added relies in the understanding of complexity arising from the modeling task itself. Alongside previous answers on the issue (J. Homer & Oliva, 2001), I would however argue that if a model is successfully calibrated on real data, it not only validates the insights offered by the modeling process itself, but it be might also useful for an “educated” evaluation of future policies.
2. Review of Literature in the field of System Dynamics

Whereas the development of System Dynamics as a discipline, initiated by Prof. Jay W Forrester and his colleagues at the MIT in the late '50s, was initially conceived as a tool to deliver computer-based model structures to analyze industrial systems, it quickly expanded to other purposes, having proved to be a reliable and useful modeling tool for complex socio-economic settings. Given this characteristic, System Dynamics thus became a popular tool in policy analysis, and this expanded to modeling the structure of illegal drug markets in order to better understand implications of existing and potential contrast policies. The first effort to model such market, or more specifically, the Heroine market in New York City, was proposed by Levin, Roberts and Hirsch in 1975, with the purpose of identifying the best drug contrast policies at city level.

Further notable efforts in the field are those of (Gardiner and Schreckengost, 1987), Everingham and Rydell (Rydell & Everingham, 1994), Behrens and Caulkis (Behrens, Caulkins, Tragler, Haunschmied, & Feichtinger, 1999), and, finally, Jack B. Homer’s (J. B. Homer, 1994) model, on which the model used in this paper is based on. In the following pages I will discuss these efforts, analyzing in greater detail Homer’s work.

2.1. 1975 “Persistent Poppy” model

Initially developed specifically for policy analysis, the model developed by Levin, Roberts and Hirsch was published as a book in 1975 under the name of “Persistent Poppy”, and later inspired further modeling efforts with its structure. The model – and here I shall point out how this work dates back to the ‘70s – identifies the main problem of drug, and more specifically, Heroin addiction in the fact that consumers would be more prone to delinquencies to fund their addiction, thus driving up micro criminality. The structure proposed in the “Persistent Poppy” is however quite convoluted, if not too complex and detailed: the model goes as far as analyzing the impact of factors such as “Personal Relevance of Arrests” and “Psychopathological Attractiveness of Addiction”. Despite these variables are indeed affecting the physiological and psychological addiction to drugs (Alexander, Beyerstein, Hadaway, & Coambs, 1981), their effect is intuitively small and could rather be summarized or compensated with the inclusion of more broad and meaningful variables.
In order to understand the rationale behind the inclusion of variables with such small effect, is important to remember the context in which this model was conceived and its ultimate goal: the “Persistent Poppy” was developed in order to better estimate local policy effect to contrast Heroine addiction and the associate street crime in a single urban area, which justify the inclusion of variables that could well be the target of specific local community efforts. For the broader national context that this research aims to model however, the significance of these factors is negligible and, thus, excludable.

2.2. Later models of 1994, 2000, 2002
The work of Everingham and Rydell in 1994 and Behrens and Caulkis in 2002 was later focused on modeling of drug initiation rates. Whereas Rydell proposes a model with first-order equations, Behrens extend the initiation rate structure with an endogenous function of prevalence, following Musto’s 1997 theory of drug epidemics: it is introduced the idea that not only the number of drug users is directly influencing the initiation rate but also the proportion of heavy to casual users matters. The argument follows the idea of a possible deterrence effect given by a higher proportion of heavy users and associated health issues, and, in Behrens and Caulkis work, this explains the inflating and bursting of drug epidemic bubbles with the following equation of initiation:

\[ \text{Initiation volume} = \tau + sLe^{q\frac{H}{L}} \]

where:
- \( \tau \) is the number of “innovators”, i.e. the users that try drug out of curiosity;
- \( s \) is the average rate at which users attract non users;
- \( q \) is a constant indicating the deterrence effect of heavy drug users;
- \( H \) & \( L \) are respectively the number of heavy and light abuse users.

Which lead to the phase plot reported in figure 3:
Other important insights offered by this model include a division of the drug user population similar to the one later used by Jack B. Homer into heavy and light addiction and a philosophical view on how the System Dynamic modeling task of the drug market work as a dynamic process itself, offering a Pirandello-esque\(^c\) perspective on the subject.

### 2.3. Jack B. Homer 1991 Model

For the purpose of a deeper understanding of the dynamics underlying the Italian illicit drugs market, this research will be mainly based on the model developed by Homer on the national cocaine prevalence in the US. First developed in 1991, Jack B. Homer model was published in the System Dynamics Review in 1994, right in the midst of what it would have been known as “the war on drugs”, which eventually resulted in a major increase in arrests related to illegal drugs trafficking and consumption. The increased fear of legal and social consequences arising from such policy are the very reasons that lead Jack Homer to develop a model that would account for a reduction in the reporting fraction of the cocaine user population in order to obtain a more realistic estimate of their number.

Whereas the model was developed with the purpose of delivering more precise estimates on the national cocaine prevalence in the period, it expresses its potential also in evaluating the effect of different scenarios, such as an increase of legal consequences of abuse, higher

\(^c\) Luigi Pirandello, Nobel Prize for Literature in 1934, was notorious for his extensive use of metatheatre, where characters of a theatrical play impersonate the role of actors in a “play within the play”. Similarly, here Behrens and Caukis acknowledge to be modeling a dynamic process while being themselves part of a dynamic process.
substances seizures, a reduction in correlated drugs abuse etc., while considering the reactions of the various sides of the market.

Structure

In his paper, Homer describes the structure of his model as "simpler" than previous efforts on the subject as to make it more clear and understandable by potential users. The model itself is divided into: a structure deemed to represent the different types of users and their interaction, a model of the market and the underlying forces determining price, purity and seizures and finally a structure representing the dynamics of underlying perceptions.

• User Population Structure

The model divides the population by two subcategories for each cocaine drug form: light and heavy users for both powder and crack cocaine, for a total of four categories. Each of these four is again subdivided into three stock variables, i.e. past month users, past year users who abstained in the last month, and people who abstained for at least one year. This last subcategory is divided once more into immune and susceptible subjects. People flow between the variables, between form of drug (from powder to crack and vice versa) and can escalate from light use to heavy use following specific rates. These two model structures are reported in figure 4:

Figure 4 - Population Structure 1 & 2 (J. B. Homer, 1994)
- **Market Structure**
  The market structure of Homer's model aims at estimating variables such as cocaine price and purity and how these are affected by different amounts of shipment seizures. These variables are then feeding back into the user population, affecting the rates at which the users initiate consumption, abstain from consumption, relapse or escalate to heavy addiction. This model component will be important especially for what concern the analysis of drug-contrast policy implications as – albeit simple – it captures all the main market forces and the associated results on supply, sales, price per gram, and purity to final users. A diagram is reported in figure 5.

![Figure 5 - Market Structure (J. B. Homer, 1994)](image)

- **Role of perceptions and overall model structure**
  The last, and most important, component of the model is represented by the structure of the public perceptions, shown in figure 6. Both market forces and user population size contribute to determine the rates at which the susceptible population initiate the consumption of drugs – as it influences the overall social exposure of the population to drug consumption and the associated stigma - but a pivotal role is also played by perception of health risks and legal risks of consumption: these two are very important factors in determining both the initiation rate to casual use
of cocaine and the escalation rate, whereas the most important drivers for abstinence rates are market factors (supply, price) and arrests.

![Model diagram]

Figure 6 - Overall Structure and Rates (J. B. Homer, 1994)

**Model output and critique**

The model's initial aim was to provide policy makers with a realistic and dynamic estimate of the reporting and—most importantly—non-reporting cocaine users in the country, assuming that legal risk and the increased associated social stigma would reduce the share of reporting users. Training the model on past data, Homer shows how his model delivers estimates consistent with publicly available data on reported cocaine users, and how the reporting and the non-reporting population reacts to basic policy changes such as an increment in arrests, seizures and associated perceptions.

This model structure is very efficient in representing the change in the reporting share of drug users over time and, for this very reason, it will be the basis this research will rely on in the quest for a dynamic and inclusive portrait of the Italian illegal market. Alongside the praise of Homer's structure, it is worth adding a brief critique, that is mostly concerning the determinants of the initiation, abstention and relapsing rates: whereas the functions themselves are undoubtedly a simplification of reality, they use the prevalence of marijuana as a measure of drug availability (therefore positively correlated with initiation and the rate of relapsing into cocaine consumption). This might not only be a bold assumption in the first place (availability of a light recreational drug might not correspond to availability of...
cocaine or – worse – crack), but it might also prove dynamically inconsistent: since the very nature of the model is relying on the assumption that there is a share of drug users that voluntarily do not self report as such, and this reporting rate is supposedly affected by an increase in legal punishment for drug consumption and possession, why would the marijuana self-reported prevalence rate also not be affected? In other words, the marijuana reporting rate might also decrease as a consequence of the introduction of a harsh drug contrast policy, thus reducing the model estimates for cocaine initiation and relapsing rates.

A possible solution for this issue might be to not consider a measure of availability at all: while this option might make logically more sense, the model could intuitively result less accurate, and leading to a poor interpretation of the dynamics involved. Another solution could be to adjust the marijuana prevalence for a given factor after the introduction of restrictive policies: this would however lead to a further discussion on how to determine such factor, that is beyond the scope of this research.

Again, considering the conceptual simplicity and the flexibility offered by this model, this research will focus on replicating Homer’s proposed structure and adapt it to the Italian market. The aim is to modify the structure to accommodate two drugs (heroin and cocaine) and recalibrate the model onto Italian data, with the final goal to offer a reliable and meaningful tool for policy analysis on the subject.

3. A note on general literature

In order to achieve a model that is plausible both in terms of its qualitative structure and its quantitative parameters, this research makes extensive use and reference to the general literature on the subject. Whereas to justify most logical structures or relationship I refer both to Italian and International research, for the analysis and tuning of the model, both in terms of numbers and specific market tendencies, I mostly refer to Italian research, reports and newspaper articles from the main editorial groups in the country (Corriere della Sera, La Repubblica, Il Sole 24 Ore etc.). More specifically, precise studies for the model calibration have been used to determine:

- The escalation rate for drug users to heavy consumption
This is mostly compared to the results of “Probability of transitioning to substance dependence among substance users (Lopez-Quintero et al., 2011)”, assuming the equivalence of “heavy use” to “addiction”. The research reports:

“After the first year of substance use onset the probability of transition to dependence was almost [...] 7.1% for cocaine users. [...] a decade after use onset was [...] 14.8% among cocaine users [...] Lifetime cumulative probability estimates indicated [...] 20.9% of cocaine users [...] users would become dependent [...]”

These values were used as a reference when building and calibrating the model and indeed the results are very close to the estimates of the report.

- **The assessment the seizure offset capacity**
  Homer in his work assumed that the organized crime is able to partially – if not fully – offset the seized quantities of imported drugs: this is intuitively especially true not only because of the immense producing capacity of the suppliers in South America (cocaine) and Afghanistan (opium – the basis for heroin), but also because of the central role of the Italian crime organizations in the European illicit drug trade\(^d\). In order to validate this assumption I mostly relied the work of Reuter, Crawford and Cave (Gordon Crawford, Jonathan Cave, 1988) alongside the International Narcotics Control Strategy Report (1993) of the US Department of State, the “Recent statistics and trend analysis of illicit drug markets” of the UNODC (UNODC, 2010) and some journalistic reportages (P. Jennings, ABC 1992), which led me to accept the inclusion of this variable in the model, using a similar offset capacity function to the one adopted by Homer’s structure. An additional insight on the pivotal role that drug cultivation has in the drug producing economies is also given by the work of Edouard Martin and Steven Symansky (2005), which help to explain the reasons behind the enormous supply of the substances at the origin.

- **The effectiveness of preventive strategies**

\(^d\) [www.fbi.gov]
The main study used to evaluate how a preventive strategy based on sensitizing the population might affect the initiation rate was the work of Griffin (Griffin & Botvin, 2010), which report a 25% decrease in the initiation rate to heavy drug consumption in the target group versus the baseline after just one year.

4. Data sources for the Italian market
The Italian government has been actively involved in the contrast of the illegal drugs trade in the last decades for many reasons. First, as explained in the introduction to this study, the import and subsequent retail sales of drugs represent the main source of income to organized crime, and age long problem in the country: an effective drug contrast policy is in fact aimed both at the reduction of the street crime associated to heavy addiction and at reducing the sources of power of the mafias. Secondly the Italian government is traditionally close the the United States and, following the '80s and '90s war on drugs on the American continent, the political consensus was against the tolerance policy adopted elsewhere (e.g. Netherlands). For this very reason the Italian Parliament created a department aimed at coordinating the public efforts in this direction: the “Dipartimento per le Politiche Antidroga”, which publishes annually a report on the status of the illegal drug market in Italy.

Most of the data used for comparison and calibration of the model proposed come form these yearly reports (Dipartimento Politiche Antidroga, 2001-2015), publicly available on the internet, which aggregate data about seizures from all law enforcement agencies, arrests and imprisonment statistics, estimates and reports of prevalence both from medical and non-medical (survey) sources. Some of the variables are integrated with the records obtained from surveys conducted by the ESPAD (European School Survey on Project of Alcohol and Other Drugs) and published in their yearly report (Guttormsson, Balakireva, Bjarnason, Kokkevi, & Kraus, 2005-2011), and by IPSAD (Italia Population Survey on Alcohol and Drugs) (IPSAD, 2003-2011).

More specifically, the variables collected and used for the calibration of the model are:

- Reported prevalence of users consuming cocaine in the last 30 days, year and more than one year
- Reported prevalence of users consuming heroin in the last 30 days, year and more than one year
- Reported prevalence of consumption of marijuana in the last month
- Average percentage of pure substance per gram for both cocaine and heroin
- Average price of substance per pure gram for both heroin and cocaine
- Seizures in kilograms for both cocaine and heroin
- Arrests for drug related crimes for both drugs
- Incarcerations for drug related crimes for both drugs

All prevalence is computed over a target population including people resident in the Italian Republic aged between 15 and 64.

It is important to note that these data were collected for all available years from 2001 and 2015 from a variety of sources and due to the very nature of these data it is hard to obtain very precise yearly records. Getting specific on how some of the data are computed, while the reported prevalence is the result of a national survey conducted every 3 years, the average purity and the average price for the two drugs are computed as the non weighted average of the price and purity of the seized quantities at retail-level. Also, the differentiation between heavy and light users is made on the basis of the reported “share of users in need of assistance”, which in this model is assumed to be the share of heavy users.

5. **Model Structure**

The model structure is based on, and indeed replicates, the one proposed by Jack B. Homer in his analysis of the national cocaine prevalence, and it is divided as well into a user population structure, a market structure and a perceptions structure. From a more technical perspective, Homer’s model was initially translated from its original iThink STELLA software form onto a Ventana Systems Vensim format: I then built onto the existing structure with the necessary additions and modifications. Some differences include separate market structures for heroin and cocaine, different role of the marijuana prevalence in the model and some additional structures to show the effect of policies on criminal revenue from drug sales.
• **User Population Structure**

The model identifies two subcategories of drug usage: light and heavy users for both cocaine and heroin, totaling four user structures. Each of these four is divided again into past month users, past year users who abstained in the last month, and people who abstained for at least one year, similarly to Jack B. Homer model. People can escalate from light (recreational) use to heavy addiction for both cocaine and heroin, can abstain, relapse in addiction and can also switch from one to the other drug. One example of this structure is reported in figure 7, obtained from the Vensim interface.

![Figure 7 - User Structure](image)

• **Market Structure**

In order to determine the market price per gram of the two substances (both pure and adulterated), their purity and the effect of seizures on these two variables, the market structure include basic model of supply, demand and seizures over total imports and – as shown in the picture below – a supply-demand ratio that influences the price per gram and the purity of the retail doses. The structure, based on the one proposed by Jack B. Homer, is duplicated to account for both drugs separately. However, whereas the data concerning purity, price and seizures is available for both drugs, it might be argued that some records – especially concerning heroin – are not detailed enough to successfully calibrate a model: while this is indeed true, the distinction of the two markets allow the model to better represent the effect that seizures have on the final
price, quality and supply of the two drugs, eventually delivering a more case-specific result. In figure 8 is reported a Vensim representation of this model component.

More specifically, this structure is based on an import variable represented as a function of expected demand and the seizures (note that the imports are modeled in such a way to partially offset seizures, addressing the previously mentioned capacity of criminal organizations to do so (Schulhofer, 1994)), and the resulting supply is then compared to the actual demand: in case of high supply-demand ratio the substance purity increases and the price decreases, whereas for a low supply-demand ratio the opposite is true. Once formed, the drug price and quality then feeds back in determining the initiation, abstention and relapsing rate of the addict population. The Supply-Demand ratio also
influences negatively the imports creating a balancing loop: for a supply significantly above the demand in fact the imports will be reduced until the two are matched.

- **The formation of the reporting rate and the role of perceptions**
  The main and most important part of the model is the one that describes the formation of perceptions and how they affect the reporting rate of the population.
  In order to analyze the effects of the shift in public policy from all points of view, three main perceptions are taken into account in the model:

  o **Perceived Safety**
    This is a measure of how safe people feel in consuming cocaine and heroin. It is negatively affected by the number of people being hospitalized due to drug consumption related issues and it is thus directly correlated with the number of heavy users of the two drugs. Since it does negatively affect the initiation rate, conceptually creates a balancing loop, similarly to what proposed by Behrens and Caulkins (look part 2.2).

  o **Perceived Legality**
    The perceived legality plays a pivotal role in the model, as it does not only impact the initiation, abstaining and relapsing rate, but also the reporting rate, the very focus of this research. The perceived legality in the model is a function of the arrests for drug related charges, both for consumption and sale (and this fits very well with the case of law n. 49/2006) and it directly relates to the effects of an increase in legal punishment, regardless of the actual incarceration rate of arrests. Compared to the equations proposed in past works, this feature - introduced for the first time by Jack B. Homer in its model - is a big addition to the structure of the initiation rate function, as it accounts for the basic and most immediate effects of legal punishment.

  o **Exposure Ratio**
    The Exposure ratio accounts for the growth in the overall prevalence of illicit drug consumption in the population and it is used as a model proxy for the public exposure to consumption of both Heroin and Cocaine (note that this effectively partially counterbalance the effect of the safety ratio).
• **The reporting rate**

It is quite intuitive that, considering the very nature and stigma associated to drug consumption, the self-reported addiction of drug users might be biased (Turner, 1998) (P. Grimm, 2010). In this research, as described above, the reporting rate is assumed to be a function of the perceived legality ratio and a baseline rate, and it directly impacts the proportion of addicts self reporting as such. The overall change of this rate will be very important from the point of view of policy evaluation, as a reporting rate decreasing over time might lead to the perception of a *faux* success of the implemented policy.

• **The determination of the actual initiation, abstinence and relapsing rates**

The two public perception measures of legality and safety are very important in determining the initiation, abstention and escalation rate, alongside the substances’ price and the prevalence of Marijuana: following up on the issue raised when criticizing Homer’s solution, the possibility that the reported prevalence of marijuana might itself be subject to changes in response to the implementation of restrictive policies is quite important for the case of this model, especially when considering the fact that, as shown in figure 9, the reported prevalence of marijuana suffer a strong decrease right after the introduction of law 49 in 2006.
In absence of alternative indicators in the general population however, for the main version of this model will still use this metric as a proxy for availability of illicit drugs, and, in order to evaluate the impact of this assumption, I will add a what-if analysis with a marijuana prevalence constant at 2007 level in Appendix A.

The final initiation function for the two drugs will be:

\[
\text{InitiationRate} = \alpha \times \text{MarijuanaPrevalence}^{\beta_1} \times \text{ExposureRatio}^{\beta_2} \times \text{PriceRatio}^{\beta_3} \times \text{PerceivedSafety}^{\beta_4} \times \text{PerceivedLegality}^{\beta_5}
\]

Consistently with what proposed by Jack B. Homer in his work and with Vlahov (Vlahov et al., 2001). Note that this function is delivering similar results to the one proposed by Behrens and Caulkins (part 2.2), but adding an important feature: the deterrence effect of a restrictive policy, represented by the inclusion of the “Perceived Legality” factor.
6. Results, analysis and implications

6.1. Model calibration and insights

The model has been calibrated on past data\(^e\) and – after some adjustments – performs well as shown in the output depicted below for the past month prevalence of cocaine:

And past month prevalence of heroin:

Where the green dots are the official reported data and the blue ones are the model estimate of the self reported prevalence in the population.

Note that the model provides us with an estimation of the actual prevalence in the population (in red) and, as it was expected, the initial small discrepancy grows bigger right at the introduction of law n.49/2006 (note that the lawmaking process in Italy is very long and the law was presented as a “decreto legislativo” in 2005 (Parlamento

\(^e\) Note that data are available until the years 2012-2013 as the prevalence surveys are taken every 3 years.
Italiano, 2006)): this it has strong implications for the final evaluation of the effectiveness of the law itself, as it does suggest that the approach of increasing the legal punishment of drug possession was more effective in reducing the reporting rate among the consumer population rather than the consumption itself. These fears are confirmed by a more detailed analysis of the reporting rate of the two drugs themselves:

Where the red series represents heroin and the blue the cocaine user reporting rates. Again it is quite clear how the model suggests a gradual decrease of the reporting rate, from an average of 85% before the introduction of the law 49/2006 to a significantly lower 55% after few years past the implementation. As can be seen on the graph, the two rates move symmetrically – this is due to a reasonable approximation of the model: as said, the reporting fractions are modeled to be influenced by a single perceived legality factor, mainly based on the arrests for drug related charges in the population. And the suggested behavior of the reporting fraction might be clearly explained by the comparison with the arrest rate:
Where the blue series shows the number of arrests suggested by the model and in red is reported the official arrest figure by year.

It can be easily observed how the model suggests that the increase in the arrest rate that followed the promulgation of the law n.49/2006 had a direct negative impact on the reporting rate. Also, the model suggests that –at the same time- the organized crime capacity to partially offset seizures allowed for a steadily growing level of imports as shown below:

Where the blue series is the official seized quantity of both drugs by year, the red series is the model estimate for the series² and in green the estimated imports. Likewise, the

² Note that the model was calibrated on the two separate drugs, whereas the results here summarized in a single graph. Note that there is no record of heroin seizures before 2007,
model proposes a price level per pure gram of the two substances: when compared with actual data, these are also quite similar (note that the heroin official prices are much more volatile due to the low number of seizures counted in computing the original statistic). In the graph below, reporting prices, the grey and red series are representing the prices suggested by the model, whereas the blue and green line are the estimated prices collected from the yearly report to the Italian parliament.

Note that the resulting supply – calculated as the estimated imports minus the estimated seizures – correspond to final retail sales revenue constantly around €5.3Billion, in line with the recent estimates of the Abele association (Il Fatto Quotidiano, 26/06/2016) for the Italian market and UNODC (UNODC, 2010).

and the aggregate value is therefore the sum of the Cocaine seizures plus an estimate for years before 2007.
6.2. Model Implications

Once observed the results suggested by the model, it is clear that such model structure has some serious implication for the way drug-contrast actions are currently evaluated: whereas some results might be represented by the number of arrests and the quantity of substance seized throughout the year, the actual impact that harshly repressive policies have on the prevalence of substance consumption in the population might be significantly misrepresented by the official surveys. In the detail of the case of the law “Fini-Giovanardi” n.49/2006, once calibrating the model to reproduce data consistent with reality, this seems to be the case for a significant share of the population as wide as almost 1% of the target population. Italian policymakers should be aware of this effect and perhaps account for it using models similar to this one when evaluating the impact of restrictive measures.

6.3. Scenario analysis

Having tuned the model on real data, it might be now interesting to simulate some possible future scenarios based on a reasonable evolution of key parameters in order to project the user prevalence of the two drug in the foreseeable future: among all the possible scenarios I selected the three that would make more sense, i.e. a baseline, a repressive and a permissive one.

Baseline

A first baseline future scenario is computed based on a constant target population (note that the Italian demographic growth is close to zero), similar marijuana prevalence, arrest and seizure rate in line with the one at the end of the recorded period (2012). This scenario would ideally represent the fact that the government did not undertook any particular countermeasure after the repeal of the law 49/2006.
Note that in this case the perceived legality is slowly stabilizing, following a flat growth of arrests after the end of 2012. This in turns re-stimulate the initiation rates, causing the prevalence of cocaine and heroin to start growing again. At the same time the reporting fraction is stabilizing around the levels of the late 2012 – also as a consequence of the flat growth in arrests – thus causing the reported rate to grow symmetrically to the actual prevalence rate in the market, but still representing only a
proportion of the actual number of addicts: here the model is showing clearly how repressive policies might have a long-lasting effect on the reporting rate of the population. It is worth noticing that this might actually be a good representation of what it is happening in these years in Italy: as picked by “La Repubblica” (11/04/2016) the first insights on the new survey proposed by the CNR (Consiglio Nazionale per le Ricerche) show a staggering increase in the reported cases of heroin compared to 2011 data: this might well be the result of the increase in actual prevalence combined with a slow growing back of the reporting fraction.

Repressive Scenario
The repressive scenario takes in consideration both the effects of higher arrests and a (perhaps consequential) reduction in the marijuana prevalence, and the impact of an increase in seizures separately, so to identify the impact of each sub-scenario.

Increase in arrests
This scenario is assuming an increase over four years of arrests of 30% over the baseline associated with a reduction of the marijuana prevalence by 30%, also accomplished progressively over four years. The suggested results are reported below:
This scenario replicates what happened in the years 2006-2014 under the law n.49/2006, with a high number of arrests and a resulting decrease in the reporting rate, and it would ideally replicate a prosecution of such policy (assuming constant seizures). The model suggests that over the course of the next 8 years such scenario would feature a reporting fraction stabilizing to the low level of 2012 – below 60% - and an actual prevalence in the population decreasing for both heroin and cocaine.

**Increase in Seizures**

For this scenario I assumed an increase in seizures of 50% over the baseline scenario, while arrests and marijuana prevalence are assumed to stay constant to the baseline after 2012.
Note how while the effect over our variables of interest — i.e. prevalence, reported prevalence and reporting rate — is indeed similar in direction to the previous scenario featuring an increased arrest rate, an increase in seizures is not affecting the actual consumption prevalence as much. This is a consequence of the fact that there is very little deterrence effect in an increase in seizures, and the only way it will impact the initiation and abstention rate of the population is through an increase in retail price per
equally-pure dose: this effect is in fact partially mitigated by the reduction in purity of the retail substance and by increased imports, jeopardizing the effect of an increase in seizures.

**Permissive Scenario**

The permissive scenario assumes a decrease of both seizures and arrests of 30% below the baseline and an increase Marijuana prevalence by 30%, all accomplished over four years. Note that this result might be compared with the proposed legalization of light drugs in the country, and it shows a significant resemblance to what happened in Colorado after the legalization of Marijuana for recreational use: as reported by the Rocky Mountain High Intensity Drug Trafficking Area report (RMHIDTA, 2015) such provisions resulted in an increase of 32% in past month marijuana use among adults in the state. First data concerning of only 6 months after the legalization suggests that the effect of such policy on the prevalence of other drugs show contradictive results, with an increase in Heroin and a slow decrease in Cocaine users (Mendelson, 2014).
The model does indeed suggest a similar growth trend for both drugs but also a slow increase in the reporting rate back to very high levels in the next years: this is due to the low readjustment of the perceived legality, that affects both the initiation rate – thus leading to the overall increase in prevalence for both drugs – and the actual reporting rate. Note that whereas in Colorado there was a full legalization of marijuana for recreational use, the model is representing a scenario of higher tolerance to illicit drug consumption in general, and its effects on cocaine and heroin prevalence in the population: the main difference is that the relationship between marijuana prevalence and the Initiation, abstention and relapse rate of both cocaine and heroin might well become insignificant in a context of full legalization, whereas in a “tolerance” scenario it make sense that such causation link is still present.

**Proposed addition**

As I will point out in the conclusion, one major issue with the current model is that it does not account for the effect of alternative repressive measures, the main being preventive sensitizing about negative health effects associated to drug consumption. Such policy has been evaluated when implemented in high school students and proved to be very effective, to the point of registering a 25% decrease (Griffin & Botvin, 2010) in heavy drugs initiation among the study group after one year. In an attempt to lay the ground for future efforts on the issue, I might propose that a similar strategy might lead to the same effectiveness among the general population, thus effectively changing the Perceived Safety rate in the initiation rate function by a factor of 25% to account for the increased awareness of the dangers associated to drugs consumption:
InitiationRate = a \times \text{MarijuanaPrevalence}^\beta \times \text{ExposureRatio}^\delta \times \text{PriceRatio}^\eta \times \text{PerceivedSafety}_{adj}^\phi \times \text{PerceivedLegality}_{adj}^\kappa

In the years after a full-scale implementation of the prevention strategy\(^6\),
A quick analysis of the baseline scenario with prevention strategy after 2012 is reported below.

\(^6\) Note that this function assumes that the exponential coefficients are calibrated onto data relative to a period with no prevention strategy.
The model suggests that the effects of such policy over the next 8 years are very significant, leading to a reduction of the prevalence of 0.5% points versus what it would have been without intervention in the case of cocaine. Of course this effect is the result of a simple addition that does not consider the other variables – perhaps on the abstention rate – that such policy might influence.

7. Conclusion and Critique of the model

The model presented in this research is undoubtedly an approximation of what the real cocaine and heroin markets are in this very moment in Italy: it does rely on the available data for its calibration – which end in 2012 – and does not include many variables that might be of interest to the policy maker, but it does a good job in capturing the dynamics of the prevalence of consumers in the target population and – specifically for the case taken in analysis, i.e. the introduction of the repressive law n.49/2006 – it does suggests that the hypothesis that increased fear of legal consequences associated with drug consumption might have caused low reporting rates is consistent with the real data. This result implies the need for policymakers to adopt new, dynamic tools that are able to model the structure and the behavior of a complex and – to many – obscure structure of the illicit drugs market: this is necessary to attain a much needed objective evaluation of past policies and a reasonable projection for future ones.

It it also important to stress that the main benefit of this and other modeling efforts in the context of system dynamics is the better understanding of the interaction of different variables and how their feedback loop influences results over time: the resulting model is an attempt to structure these interactions so to provide meaningful estimates of the actual prevalence of both
In recognizing the limits of such effort, I shall point out that greater confidence could be obtained not only through the recording and adoption of more accurate data, but also with the inclusion of additional loops. Namely, the model does not include a full range of repressive measure alternative to arrests and seizures: these might include preventive strategies and sensitizing, loss of some civil rights as a consequence of consumption (e.g. perpetual withdrawal of driving license), partial legalization of drugs etc. In the proposed addition part, I investigate the basic addition of a structure representing the effects of a sensitizing effort on the initiation rate of the target population: this however not accounting for additional effects that such policy might have on existing users, nor it is depending on a budget constraint or any measure in the addicted population; a proposal for a future work might be the addition of a link between the prevalence in the population and the prevention effort. Another critical issue is the fact that the model does not account for the possibility that the official marijuana prevalence rate itself might be biased by a dynamic reporting rate: this concern might be addressed in the future by a further analysis of how the reporting rates change by type of drug or by integrating the model with an endogenous structure the formation of the marijuana prevalence rate. A significant model extension for the Italian market might be the integration with data from the rest of the European Union and other destination markets: Italy is notoriously a transit market for a significant share of the drug smuggled into other European market, and it might make sense to account for the general level of European imports when accounting for the offset capacity of the criminal organizations.
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Appendix A

What if analysis

What if the actual marijuana prevalence rate stayed to the 2007 level after the introduction of law n.49/2006? Similarly to what Homer did in his work, in this research the marijuana prevalence rate has been considered a reliable metric even if, as pointed out in the main text, it would make sense that this rate drops as a consequence of the introduction of repressive policies. Performing a second computer calibration on past data and adopting a constant prevalence rate of past month consumption of marijuana equal to 2007 levels for the entire 2007-2012 period, the model provided the following results for our main variables of interest:
Despite the similarity of this output to the one in eventually used in the model, some clear differences stand out. Namely, with the marijuana prevalence rate staying at high levels after 2007, the deterrence effect of a higher number of arrests is partially offset, and the prevalence of both cocaine and heroin continue to rise – yet at a lower pace – after the introduction of law 49 of 2006. The reporting rate falls even lower than in the case used in the final research, and the reported prevalence does not quite match the actual data. Overall this second calibration seems not to add much in terms of explanatory power and on the contrary suggests a lower fit for the reported prevalence of the two drugs. Acknowledging the fact that the truth – as always – is arguably lying in the middle, the main research will accept the hypothesis that the reported marijuana prevalence is reliable enough to deliver a reasonable and meaningful analysis of the Italian scenario of the time.
Appendix B

Functions of the main structures of the model

************************************************************
.Control
************************************************************

Simulation Control Parameters

FINAL TIME = 2020
Units: Year
:GROUP .Control
The final time for the simulation.

INITIAL TIME = 2001
Units: Year
:GROUP .Control
The initial time for the simulation.

SAVEPER = TIME STEP
Units: Year [0,?] 
:GROUP .Control
The frequency with which output is stored.

TIME STEP = 0.125
Units: Year [0,?] 
:GROUP .Control
The time step for the simulation.

************************************************************
.Final Model
************************************************************

************************************************************
.Supply/Demand
************************************************************

Cal Price Coc Baseline = 7.19
Units: Dmnl
:GROUP .Supply/Demand

Change in Expected Demand = ( Consump Demand Coc - Expected Demand ) / 0.5
Units: KG/(Year*Year)
:GROUP .Supply/Demand
Change in the expected demand as a function of the actual consumption

Change in Expected Purity = IF THEN ELSE ( Purity > Expected Purity , ( Purity - Expected Purity ) / 0.5, ( Purity - Expected Purity ) / 1)
Units: Dmnl
Change in expected purity given the current substance purity

\[
\text{Change in Expected Supply} = \frac{(\text{Supply} - \text{Expected Supply})}{0.5}
\]

Units: KG/(Year*Year)

Change in the expected supply as a function of the current supply

\[
\text{Change in S D ratio} = \frac{\text{Supply Demand Ratio} - \text{Recent S D Ratio}}{0.5}
\]

Units: Dmnl

Change in the Supply - Demand Ratio

Consump Demand Coc = Cons Demand By LUs + Cons Demand by HUs

Units: KG/Year

DEA Price Adultered = DEA Purity * DEA Price pureGm

Units: Euro/Gram

DEA Price pureGm = Official Price pureGm coc * 1.354

Units: Euro/Gram

DEA Purity = Purity Table (Year)

Units: Dmnl

Effect od Supply Demand Ratio on Import = 1 / Recent S D Ratio

Units: Dmnl

This fraction represent the effect that the Supply - Demand Ratio has on the final imports

Expected Demand = INTEG( Change in Expected Demand , 12000)

Units: KG/Year

Expected Purity = INTEG( Change in Expected Purity , 0.63)

Units: Dmnl

Expected Seiz frac = SMOOTH3I ( Seizes Fraction Imports , 0.5, 0.2)

Units: Dmnl

Expected Supply = INTEG( Change in Expected Supply , 12000)

Units: KG/Year
Imports = Effect of Supply Demand Ratio on Import * Expected Demand * Imports Expansion Multiplier * Seiz Offset Multiplier

Units: KG/Year
  :GROUP .Supply/Demand
Total Imports in Italy, considering the expected demand, the current supply-demand ratio and the expected seizures

Imports Expansion Multiplier = 1.17
Units: Dmnl
  :GROUP .Supply/Demand

Indic Seiz Offset = 1 / (1 - Expected Seiz frac)
Units: Dmnl
  :GROUP .Supply/Demand

Min Price pureGm = 5
Units: Euro/Gram
  :GROUP .Supply/Demand

Units: Dmnl
  :GROUP .Supply/Demand

Official Cocaine Seizures = IF THEN ELSE (Year > 2012, Seizures of Cocaine, NNICC Seizures Table (Year))
Units: KG/Year
  :GROUP .Supply/Demand

Official Price pureGm coc = IF THEN ELSE (Year > 2012 :OR: Year = 2005 :OR: Year = 2007, Price pureGm Cocaine, Price pure table (Year))
Units: Euro/Gram
  :GROUP .Supply/Demand

Price Adulterated = Purity * Price pureGm Cocaine
Units: Dollar/Unit
  :GROUP .Supply/Demand
Retail price of the adulterated substance

Units: Dmnl
  :GROUP .Supply/Demand

Price pureGm Cocaine = MAX (Min Price pureGm, EXP (Cal Price Coc Baseline - 0.92 * L.N (Expected Supply / 1000)) * 1.354)
Units: Euro/Gram
:GROUP .Supply/Demand
Price per Gram of pure cocaine

Purity = MIN ( 1, Supply Demand Ratio * Expected Purity )
Units: Dmnl
:GROUP .Supply/Demand
Purity as a function of supply demand ratio

Purity Pct = Purity * 100
Units: Dmnl
:GROUP .Supply/Demand

Purity Table (([2000,0.4)-
(2014,0.7]),(2000,0.63),(2001,0.65),(2002,0.59),(2003,0.64),(2004,0.55),(2006,0.55),(2008,0.
47),(2009,0.47),(2010,0.46),(2011,0.47),(2012,0.5),(2013,0.6)
,(2014,0.55) )
Units: Dmnl
:GROUP .Supply/Demand

Recent S D Ratio = INTEG( Change in S D ratio , 1)
Units: Dmnl
:GROUP .Supply/Demand
The perceived current Supply - Demand ratio

Retail sales Cocaine = Supply * Price pureGm Cocaine * 1000
Units: Euro/Year
:GROUP .Supply/Demand

Seiz Frac Imp Baseline = Seiz Frac Imp Baseline Table ( Year )
Units: Dmnl
:GROUP .Supply/Demand

Seiz Offset Multiplier = Seiz Offset Multiplier Serie ( Indic Seiz Offset )
Units: Dmnl
:GROUP .Supply/Demand
This multiplier represents the criminal organizations capacity to partially offset the seizures

Seiz Offset Multiplier Serie ([(1,1)-
(1.5,1.9)],(1,1),(1.05,1.05),(1.1,1.1),(1.15,1.14),(1.2,1.17),(1.25,1.18),(1.5,1.18) )
Units: Dmnl
:GROUP .Supply/Demand

Seizes Fraction Imports = seizure multiplier * Seiz Frac Imp Baseline
Units: Dmnl
:GROUP .Supply/Demand
Fraction of imports that is seized by the authorities

seizure multiplier = 1 - ( 1 - Seizure Switch ) * RAMP ( 0.33, 2012, 2018)
Units: Dmnl
:GROUP .Supply/Demand

Seizures of Cocaine = Imports * Seizes Fraction Imports
Units: KG/Year
:GROUP .Supply/Demand
Seizures in Italy as a fraction of exports

Supply = MAX ( 0, Imports - Seizures of Cocaine )
Units: KG/Year
:GROUP .Supply/Demand

Supply Demand Ratio = Supply / Consump Demand Coc
Units: Dmnl
:GROUP .Supply/Demand

Year = Time
Units: Year
:GROUP .Supply/Demand

***************
.User Structure
***************

Cal LUC Escalation Rate = 0.0735
Units: Dmnl
:GROUP .User Structure
Rate of Past Month Light Users switching to Heavy Use

Immune NPY LUCs = INTEG( LUC Permanent 1yr Abstaining - INPY LUC Deaths , 542181)
Units: People
:GROUP .User Structure

Incarcerat LUC = Arrests LUC * Incarc Frac Arrests
Units: People/Year
:GROUP .User Structure

Initiation to Cocaine = Never Users * Initiation to Cocaine rate 1
Units: People/Year
:GROUP .User Structure
Initiation rate per Year to cocaine

INPY LUC Death Rate = 0.003
Units: Dmnl
:GROUP .User Structure
death rate Among immune past light users of cocaine

INPY LUC Deaths = INPY LUC Death Rate * Immune NPY LUCs
Units: People/Year
:GROUP .User Structure
Immune past light users of powder cocaine dying per year

\[ \text{LUC 1Mo Abstain} = \text{Past Mo Light Cocaine} \times \text{LUC Abstain Rate} + \text{Incarcerat LUC} \]
Units: People/Year
\[ \text{GROUP .User Structure} \]
Past Month Users who start abstaining per year

\[ \text{LUC Escalation} = \text{Past Mo Light Cocaine} \times \text{Cal LUC Escalation Rate} \]
Units: People/Year
\[ \text{GROUP .User Structure} \]
Last Month Light Users Escalating Per year

\[ \text{LUC Permanent 1yr Abstaining} = \text{Past Yr NPM LUCs} \times \text{LUC Permanent 1Yr Abstension Rate} \]
Units: People/Year
\[ \text{GROUP .User Structure} \]
Past Year Light Users of Cocaine non Past month Permanently Abstaining

\[ \text{LUC Permanent 1Yr Abstension Rate} = 0.25 \]
Units: Dmnl
\[ \text{GROUP .User Structure} \]
Rate of People Abstaining

\[ \text{LUC Switch to Cocaine} = \text{MAX} (0, \text{Past Mo Light Heroin} \times \text{LUH Switch to C Rate}) \]
Units: People/Year
\[ \text{GROUP .User Structure} \]
Last Month Light Crack Users switching to Cocaine per month

\[ \text{LUC Switch to H Rate} = \text{Past Mo Light Cocaine} \times \text{LU Sw to Heroin Rate} \]
Units: People/Year
\[ \text{GROUP .User Structure} \]
Last Month Light cocaine Users switching to heroin per month

\[ \text{LUC Tempor 1yr Abstaining} = (1 - \text{LUC Permanent 1Yr Abstension Rate}) \times \text{Past Yr NPM LUCs} \]
Units: People/Year
\[ \text{GROUP .User Structure} \]
Light Users Of cocaine Last Year non Past Month Temporarily Abstaining per year

\[ \text{Yearly LUC Switch to Cocaine} = \text{LUC Switch to Cocaine} \]
Units: People/Year
\[ \text{GROUP .User Structure} \]
LUHs switching to cocaine yearly

\[ \text{Never Users} = \text{Target Population} - \text{Ever Users} \]
Units: People
\[ \text{GROUP .User Structure} \]
People that never used cocaine

\[ \text{NPY LUC Relapse Rate} = 0.7987 \]
Units: Dmnl


`:GROUP .User Structure

NPY LUC Relapsing = Suscepts NPY LUCs * NPY LUC Relapse Rate
   Units: People/Year
`:GROUP .User Structure
Susceptible non past year light cocaine users relapsing into monthly usage each year

Past Mo Light Cocaine = INTEG( Initiation to Cocaine + Yearly LUC Switch to Cocaine +
NPY LUC Relapsing + Past Year LUC Relapsing - LUC Switch to H Rate - LUC 1Mo Abstain -
LUC Escalation
   - PM LUC Death, Cal Initial PMO Cocaine Light Users )
   Units: People
`:GROUP .User Structure
Past Month Users of Cocaine

Past Year LUC Relapsing = PYLUC Relapse Rate 1 * Past Yr NPM LUCs
   Units: People/Year
`:GROUP .User Structure
Past Year Non Past Month Light cocaine Users relapsing into Monthly Usage

Past Year Non Past Mo LUC Deaths = PYNPMLUC death Rate * Past Yr NPM LUCs
   Units: People/Year
`:GROUP .User Structure
yearly Deaths of Past Year non Past Month Light Users Of Cocaine

Past Yr NPM LUCs = INTEG( LUC 1Mo Abstain - LUC Permanent 1yr Abstaining - LUC
Tempor 1yr Abstaining - Past Year LUC Relapsing - Past Year Non Past Mo LUC Deaths ,
350823)
   Units: People
`:GROUP .User Structure

PM LUC Death = PM LUC Death Rate * Past Mo Light Cocaine
   Units: People/Year
`:GROUP .User Structure
Last Month light cocaine users dying per year

PM LUC Death Rate = 0.002
   Units: Dmnl
`:GROUP .User Structure
Death Rate among past month light cocaine users

PYNPMLUC death Rate = 0.002
   Units: Dmnl
`:GROUP .User Structure
Death Rate among Past Year Non Past Month Light Users of Cocaine

SNPY Death Rate = 0.003
   Units: Dmnl
`:GROUP .User Structure
Susceptible non past year light cocaine users death rate
SNPY LUC Deaths = Suscepts NPY LUCs * SNPY Death Rate
Units: People/Year
:GROUP .User Structure
Susceptible non past year light cocaine users deaths

Suscepts NPY LUCs = INTEG( LUC Tempor 1yr Abstaining - NPY LUC Relapsing - SNPY LUC Deaths, 542181)
Units: People
:GROUP .User Structure

*****************************************************************************************
.Legality Ratio
*****************************************************************************************

Arr Poss CocHer = Arr Possess Coc
Units: People/Year

Arr Possess Coc = Indic Arrests Poss * Arrest Multiplier
Units: People/Year

Arr Sales Mfr CoC = Indic Arrests Sales * Arrest Multiplier
Units: People/Year

Arr SalesMfr CocHer = Arr Sales Mfr CoC
Units: People/Year

Arrest Baseline = 33872
Units: People

Arrest Boost = Arrest Boost Table ( Year )
Units: Dmnl

Arrest Boost Table ( [2002,-0.2)-(2015,0.5)],(2000,0),(2003,0),(2004,-0.0770843),(2005,0.271434),(2006,0.33848),(2007,0.42206),(2008,0.491497),(2009,0.398235),(2011,0.161343),(2012,0.0990198),(2013,0.0482109),(2014,0.00301134),(2015,-0.129842) )
Units: Dmnl

Arrest Cap = 1e+07
Units: People

Arrest Coc = Indic Arrests Coc * Arrest Multiplier
Units: People/Year

Arrest Multiplier = 1 - ( 1 - MIN ( Arrest Cap / Indic Arrests Coc , Arrest Switch ) ) * RAMP ( 0.33, 2012, 2018)
Units: Dmnl

Arrest Ratio = Arrest Coc / Arrest Baseline
Units: Dmnl

Arrest Switch = 1
Units: Dmnl

Arrests CocHer = Arr SalesMfr CocHer + Arr Poss CocHer
Units: People/Year

Arrests HU = Ind Arrests HU * Arrest Multiplier
Units: People/Year

Arrests HUC = Indic Arrests HUC * Arrest Multiplier
Units: People/Year

Arrests HUH = Indic Arrests HUH * Arrest Multiplier
Units: People/Year

Arrests LU = Ind Arrests LU * Arrest Multiplier
Units: People/Year

Arrests LUC = Indic Arrests LUC * Arrest Multiplier
Units: People/Year

Arrests LUH = Indic Arrests LUH * Arrest Multiplier
Units: People/Year

Cal Arrests Cocaine Heavy Users Poss = 0.01
Units: Dmnl

Cal Arrests Cocaine Heavy Users Sales = 0.1
Units: Dmnl

Cal Arrests Cocaine Light Users Poss = 0.0068
Units: Dmnl

Cal Arrests Cocaine Light Users Sales = 0.0246
Units: Dmnl

Cal Arrests Heroin Heavy Users Poss = 0.01
Units: Dmnl

Cal Arrests Heroin Heavy Users Sales = 0.1
Units: Dmnl

Cal Arrests Heroin Light Users Poss = 0.00867
Units: Dmnl

Cal Arrests Heroin Light Users Sales = 0.061
Units: Dmnl
Cal Pvc Legality Ratio = 0.8
Units: Dmnl

Eff Size Arr Sales = Min Eff Size Arr Sales + ( 1 - Min Eff Size Arr Sales ) * seizure multiplier
Units: Dmnl

HU Frac of Arrests = Arrests HU / Arrest Coc
Units: Dmnl

Incarc Frac Arrests = Incarc Fractions Arrests Table ( Year )
Units: Dmnl

Incarc Frac Arrests Table ( Year )
[(2005,0.50),(2006,0.536736),(2007,0.536736),(2008,0.616308),(2009,0.616308),(2010,0.616308),(2011,0.640084),(2012,0.654989),(2013,0.597079)]
Units: Dmnl

Incarcerat Coc = Arrest Coc * Incarc Frac Arrests
Units: People/Year

Incarcerat HU = Incarcerated HU + Incarcerated HUH
Units: People/Year

Incarcerated HUC = Incarc Fractions Arrests * Arrests HUC
Units: People/Year

Incarcerated HUH = Incarc Fractions Arrests * Arrests HUH
Units: People/Year

Incarcerated LUC = Arrests LUC * Incarc Fractions Arrests
Units: People/Year

Incarcerated LUH = Incarc Fractions Arrests * Arrests LUH
Units: People/Year

Ind Arr Poss HUC = Cal Arrests Cocaine Heavy Users Poss * Past Mo Heavy Cocaine * ( 1 + Arrest Boost )
Units: People/Year

Ind Arr Poss HUH = Cal Arrests Heroin Heavy Users Poss * Past Mo Heavy Heroin * ( 1 + Arrest Boost )
Units: People/Year

Ind Arr Poss LUC = Cal Arrests Cocaine Light Users Poss * Past Mo Light Cocaine * ( 1 + Arrest Boost )
Units: People/Year

Ind Arr Poss LUH = Cal Arrests Heroin Light Users Poss * Past Mo Light Heroin * ( 1 + Arrest Boost )
Units: People/Year
Units: People/Year

\[ \text{Ind Arr Sales HUC} = \text{Cal Arreets Cocaine Heavy Users Sales} \times \text{Past Mo Heavy Cocaine} \times (1 + \text{Arrest Boost}) \times \text{Eff Size Arr Sales} \]
Units: People/Year

\[ \text{Ind Arr Sales HUH} = \text{Cal Arreets Heroin Heavy Users Sales} \times \text{Past Mo Heavy Heroin} \times (1 + \text{Arrest Boost}) \times \text{Eff Size Arr Sales} \]
Units: People/Year

\[ \text{Ind Arr Sales LUC} = \text{Cal Arreets Cocaine Light Users Sales} \times \text{Past Mo Light Cocaine} \times (1 + \text{Arrest Boost}) \times \text{Eff Size Arr Sales} \]
Units: People/Year

\[ \text{Ind Arr Sales LUH} = \text{Cal Arreets Heroin Light Users Sales} \times \text{Past Mo Light Heroin} \times (1 + \text{Arrest Boost}) \times \text{Eff Size Arr Sales} \]
Units: People/Year

\[ \text{Ind Arreets HU} = \text{Indic Arreets HUC} + \text{Indic Arreets HUH} \]
Units: People/Year

\[ \text{Ind Arreets LU} = \text{MAX}(0, \text{Indic Arreets LUC} + \text{Indic Arreets LUH}) \]
Units: People/Year

\[ \text{Indic Arreets Coc} = \text{Ind Arreets LU} + \text{Ind Arreets HU} \]
Units: People/Year

\[ \text{Indic Arreets HUC} = \text{Ind Arr Sales HUC} + \text{Ind Arr Poss HUC} \]
Units: People/Year

\[ \text{Indic Arreets HUH} = \text{Ind Arr Sales HUH} + \text{Ind Arr Poss HUH} \]
Units: People/Year

\[ \text{Indic Arreets LUC} = \text{Ind Arr Sales LUC} + \text{Ind Arr Poss LUC} \]
Units: People/Year

\[ \text{Indic Arreets LUH} = \text{Ind Arr Sales LUH} + \text{Ind Arr Poss LUH} \]
Units: People/Year

\[ \text{Indic Arreets Poss} = \text{Ind Arr Poss HUH} + \text{Ind Arr Poss HUC} + \text{Ind Arr Poss LUH} + \text{Ind Arr Poss LUC} \]
Units: People/Year

\[ \text{Indic Arreets Sales} = \text{Ind Arr Sales HUH} + \text{Ind Arr Sales HUC} + \text{Ind Arr Sales LUH} + \text{Ind Arr Sales LUC} \]
Units: People/Year

\[ \text{Min Eff Size Arr Sales} = 0.5 \]
Units: Dmnl
Official Arr Possession = Official Arrest Possession Table (Year)
   Units: People/Year

Official Arr SalesMfr = Official Arrest Sales Mfr Table (Year)
   Units: People/Year

Official Arrest Possession Table ([(2001,0)-(2015,0)],(2001,0),(2015,0))
   Units: Dmnl

   Units: Dmnl

Official Arrests CocHer = IF THEN ELSE (Year > 2012, Arrests CocHer, Official Arr SalesMfr + Official Arr Possession)
   Units: People/Year

Pcvd Arrest Ratio Logic = smooth (Arrest Ratio, 3)
   Units: Dmnl

Pcvd Arrest Ratio Lower = smooth (Arrest Ratio, 0.25)
   Units: Dmnl

Pcvd Arrest Ratio Upper = SMoothi (Arrest Ratio, 3, 1)
   Units: Dmnl

Perceived Arrest Ratio = IF THEN ELSE (Arrest Ratio < 0.65 * Pcvd Arrest Ratio Logic, Pcvd Arrest Ratio Lower, Pcvd Arrest Ratio Upper)
   Units: Dmnl

Seizure multiplier = 1 - (1 - Seizure Switch) * RAMP (0.33, 2012, 2018)
   Units: Dmnl

Seizure Switch = 1
   Units: Dmnl

******************************************************************************
  Safety Ratio
******************************************************************************

Cal Pcvd Safety Ratio = 0.8
   Units: Dmnl

Cons Demand by HUs = (12 / 1000) * (Past Mo Heavy Cocaine * 8)
   Units: KG/Year

Cons Demand By LUs = (12 / 1000) * (Past Mo Light Cocaine * 0.5)
   Units: KG/Year
Consumption Demand Coc = Cons Demand By LUs + Cons Demand by HUs
Units: KG/Year

Consumption Demand Her = (12 / 1000) * (Past Mo Heavy Heroin * 8 + Past Mo Light Heroin * 0.5)
Units: KG/Year

DAWN ER Mentions = DAWN ER Mentions Table (Year)
Units: People/Year

DAWN ER Mentions Table = [(2001,4500)-(2015,5000)],(2001,4500),(2015,5000)
Units: People/Year

DAWN ME Mentions = DAWN ME Mentions Table (Year)
Units: People/Year

DAWN ME Mentions Table = [(2001,500)-(2015,510)],(2001,503),(2015,500)
Units: People/Year

ER Mentions = ER Mentions LUs + ER Mentions HUs
Units: People/Year

ER Mentions Adj Factor = (2001,0.6),(2015,0.6)
Units: People/Year

ER Mentions Adjusted = ER Mentions * ER Mentions Adj Factor (Year)
Units: People/Year

ER Mentions bsline = 1000
Units: People/Year

ER Mentions HUs = Past Mo Heavy Cocaine * 0.003 + Past Mo Heavy Heroin * 0.035
Units: People/Year

ER Mentions LUs = Past Mo Light Cocaine * 0.0001 + Past Mo Light Heroin * 0.0035
Units: People/Year

HU Frac of Consumption = Cons Demand by HUs / Consump Demand Coc
Units: Dmnl

HU Frac of ER = ER Mentions HUs / ER Mentions
Units: Dmnl

ME Mentions = Past Mo Heavy Cocaine * 0.00018 + Past Mo Light Cocaine * 1e-05 + Past Mo Heavy Heroin * 0.00155 + Past Mo Light Heroin * 0.0004
Units: People/Year

Morbidity Ratio = ER Mentions / ER Mentions bsline
Units: Dmnl
Past Mo Heavy Cocaine = INTEG( HUH Switch to C + Yearly LUP Escalation + NPY HUP Relapsing + Past Year HUP Relapsing - HUP 1Mo Abstain - HUP Switch to Crack Rate - PM HUP Deaths 
, Cal Initial PMO Cocaine Heavy Users )
Units: People

Past Mo Heavy Heroin = INTEG( HUP Switch to C Yearly + Yearly LUC Escalation + NPY HUC Relapsing + Past Year HUC Relapsing - HUC 1Mo Abstain - HUC Switch to Heroin Yearly - 
PM HUC Deaths , Cal Initial PMO Heroin Heavy Users )
Units: People

Past Mo Light Cocaine = INTEG( Initiation to Cocaine + Yearly LUC Switch to Cocaine + NPY LUC Relapsing + Past Year LUC Relapsing - LUC Switch to H Rate - LUC 1Mo Abstain - LUC Escalation 
- PM LUC Death , Cal Initial PMO Cocaine Light Users )
Units: People
Past Month Users of Cocaine

Past Mo Light Heroin = INTEG( Initiation to Heroin + Yearly LUC Switch to H + NPY LUH Relapsing + Past Year LUH Relapsing - LUH 1Mo Abstain - LUH Escalation - LUC Switch to Cocaine 
- PM LUH Death , Cal Initial PMO Heroin Light Users )
Units: People

Pcvd Morbidity Ratio = SMOOTHI ( Morbidity Ratio , 3, 20.19)
Units: Dmnl

Pcvd Safety Ratio = Pcvd Morbidity Ratio ^ ( - Cal Pcvd Safety Ratio )
Units: Dmnl

Year = Time
Units: Year

*******************************************************************************
..Supply/Demand
*******************************************************************************

Cal Price Coc Baseline = 7.19
Units: Dmnl

Change in Expected Demand = ( Consump Demand Coc - Expected Demand ) / 0.5
Units: KG/(Year*Year)
Change in the expected demand as a function of the actual consumption

Change in Expected Purity = IF THEN ELSE ( Purity > Expected Purity , ( Purity - Expected Purity ) / 0.5, ( Purity - Expected Purity ) / 1)
Units: Dmnl
Change in expected purity given the current substance purity
Change in Expected Supply = (Supply - Expected Supply) / 0.5
Units: KG/(Year*Year)
Change in the expected supply as a function of the current supply

Change in S D ratio = (Supply Demand Ratio - Recent S D Ratio) / 0.5
Units: Dmnl
Change in the Supply - Demand Ratio

DEA Price Adultered = DEA Purity * DEA Price pureGm
Units: Euro/Gram

DEA Price pureGm = Official Price pureGm coc * 1.354
Units: Euro/Gram

DEA Purity = Purity Table (Year)
Units: Dmnl

Effect of Supply Demand Ratio on Import = 1 / Recent S D Ratio
Units: Dmnl
This fraction represents the effect that the Supply - Demand Ratio has on the final imports

Expected Demand = INTEG(Change in Expected Demand, 12000)
Units: KG/Year

Expected Purity = INTEG(Change in Expected Purity, 0.63)
Units: Dmnl

Expected Seiz frac = SMOOTH3I(Seizes Fraction Imports, 0.5, 0.2)
Units: Dmnl

Expected Supply = INTEG(Change in Expected Supply, 12000)
Units: KG/Year

Imports = Effect of Supply Demand Ratio on Import * Expected Demand * Imports Expansion Multiplier * Seiz Offset Multiplier
Units: KG/Year
Total Imports in Italy, considering the expected demand, the current supply-demand ratio and the expected seizures

Imports Expansion Multiplier = 1.17
Units: Dmnl

Indic Seiz Offset = 1 / (1 - Expected Seiz frac)
Units: Dmnl

Min Price pureGm = 5
Units: Euro/Gram
NNICC Seizures Table ([(2001,0)-
Units: Dmnl

Official Cocaine Seizures = IF THEN ELSE ( Year > 2012, Seizures of Cocaine , NNICC
Seizures Table ( Year )
Units: KG/Year

Official Price pureGm coc = IF THEN ELSE ( Year > 2012 :OR: Year = 2005 :OR: Year =
2007, Price pureGm Cocaine , Price pure table ( Year ) )
Units: Euro/Gram

Price Adulterated = Purity * Price pureGm Cocaine
Units: Dollar/Unit
Retail price of the adulterated substance

Price pure table ([(2001,100)-
,(2012,139.9) )
Units: Dmnl

Price pureGm Cocaine = MAX ( Min Price pureGm , EXP ( Cal Price Coc Baseline - 0.92 *
LN ( Expected Supply / 1000 ) ) * 1.354)
Units: Euro/Gram
Price per Gram od pure cocaine

Purity = MIN ( 1, Supply Demand Ratio * Expected Purity )
Units: Dmnl
Purity as a function of supply demand ratio

Purity Pct = Purity * 100
Units: Dmnl

Purity Table ([(2000,0.4)-
(2014,0.7)],(2000,0.63),(2001,0.65),(2002,0.59),(2003,0.64),(2004,0.55),(2006,0.55),(2008,0.47),(2009,0.47),(2010,0.46),(2011,0.47),(2012,0.5),(2013,0.6)
,(2014,0.55) )
Units: Dmnl

Recent S D Ratio = INTEG( Change in S D ratio , 1)
Units: Dmnl
The perceived current Supply - Demand ratio

Retail sales Cocaine = Supply * Price pureGm Cocaine * 1000
Units: Euro/Year

Seiz Frac Imp Baseline = Seiz Frac Imp Baseline Table ( Year )

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Seiz Offset Multiplier = Seiz Offset Multiplier Serie (Indic Seiz Offset)
Units: Dmnl
This multiplier represents the criminal organizations capacity to partially offset the seizures

Seiz Offset Multiplier Serie ([1,1), (1.5,1.9), (1.1,1.1), (1.15,1.14), (1.2,1.17), (1.25,1.18), (1.5,1.18)]
Units: Dmnl

Seizes Fraction Imports = seizure multiplier * Seiz Frac Imp Baseline
Units: Dmnl
Fraction of imports that is seized by the authorities

Seizures of Cocaine = Imports * Seizes Fraction Imports
Units: KG/Year
Seizures in Italy as a fraction of exports

Supply = MAX(0, Imports - Seizures of Cocaine)
Units: KG/Year

Supply Demand Ratio = Supply / Consump Demand Coc
Units: Dmnl

User Structure

Cal LUC Escalation Rate = 0.0735
Units: Dmnl
Rate of Past Month Light Users switching to Heavy Use

Immune NPY LUCs = INTEG(LUC Permanent 1yr Abstaining - INPY LUC Deaths, 542181)
Units: People

Initiation to Cocaine = Never Users * Initiation to Cocaine rate 1
Units: People/Year
Initiation rate per Year to cocaine

INPY LUC Death Rate = 0.003
Units: Dmnl
death rate Among immune past light users of cocaine

INPY LUC Deaths = INPY LUC Death Rate * Immune NPY LUCs
Units: People/Year
Immune past light users of cocaine cocaine dying per year

LUC 1Mo Abstain = Past Mo Light Cocaine * LUC Abstain Rate 1 + Incarcerat LUC
Units: People/Year
Past Month Users who start abstaining per year

$LUC_{\text{Escalation}} = \text{Past Mo Light Cocaine} \times \text{Cal LUC Escalation Rate}$

Units: People/Year

Last Month Light Users Escalating Per Month

$LUC_{\text{Permanent 1yr Abstaining}} = \text{Past Yr NPM LUCs} \times \text{LUC Permanent 1Yr Abstension Rate}$

Units: People/Year

Past Year Light Users of Cocaine non Past month Permanently Abstaining

$LUC_{\text{Permanent 1Yr Abstension Rate}} = 0.25$

Units: Dmnl

Rate of People Abstaining

$LUC_{\text{Switch to Cocaine}} = \text{MAX} (0, \text{Past Mo Light Heroin} \times \text{LUH Switch to C Rate})$

Units: People/Year

Last Month Light Crack Users switching to Cocaine per month

$LUC_{\text{Switch to H Rate}} = \text{Past Mo Light Cocaine} \times \text{LU Sw to Heroin Rate}$

Units: People/Year

Last Month Light Cocaine Users switching to Crack per month

$LUC_{\text{Tempor 1yr Abstaining}} = (1 - LUC_{\text{Permanent 1Yr Abstension Rate}}) \times \text{Past Yr NPM LUCs}$

Units: People/Year

Light Users Of cocaine Last Year non Past Month Temporarily Abstaining per year

Monthly LUC Switch to Cocaine = LUC Switch to Cocaine

Units: People/Year

LUCs switching to Cocaine Yearly

Never Users = Target Population - Ever Users

Units: People

People that never used cocaine

$NPY\ LUC_{\text{Relapse Rate}} = 0.7987$

Units: Dmnl

$NPY\ LUC_{\text{Relapsing}} = \text{Suscepts NPY LUCs} \times \text{NPY LUC Relapse Rate}$

Units: People/Year

Susceptible non past year light cocaine users relapsing into monthly usage each year

Past Year LUC Relapsing = $PYLUC_{\text{Relapse Rate 1}} \times \text{Past Yr NPM LUCs}$

Units: People/Year

Past Year Non Past Month Light cocaine Users relapsing into Monthly Usage
Past Year Non Past Mo LUC Deaths = PYNPMLUCs death Rate * Past Yr NPM LUCs
Units: People/Year
yearly Deaths of Past Year non Past Month Light Users Of Cocaine

Past Yr NPM LUCs = INTEG( LUC 1Mo Abstain - LUC Permanent 1yr Abstaining - LUC Tempor 1yr Abstaining - Past Year LUC Relapsing - Past Year Non Past Mo LUC Deaths, 350823)
Units: People

PM LUC Death = PM LUC Death Rate * Past Mo Light Cocaine
Units: People/Year
Last Month light cocaine users dying per Year

PM LUC Death Rate = 0.002
Units: Dmnl
Death Rate among past month light cocaine users

PYNPMLUC death Rate = 0.002
Units: Dmnl
Death Rate among Past Year Non Past Month Light Users of Cocaine

PYNPMLUCs death Rate = 0.002
Units: Dmnl

SNPY Death Rate = 0.003
Units: Dmnl
Susceptible non past year light cocaine users death rate

SNPY LUC Deaths = Suspects NPY LUCs * S NPY Death Rate
Units: People/Year
Susceptible non past year light cocaine users deaths

Suscepts NPY LUCs = INTEG( LUC Tempor 1yr Abstaining - NPY LUC Relapsing - S NPY LUC Deaths, 542181)
Units: People

Rates Formation

Cal Abstain Coc = 2.908
Units: Dmnl

Cal Abstain Her = 2.46
Units: Dmnl

Cal Coc Expo = 0.4
Units: Dmnl

Cal Coc Marij = 0.3809
Cal Her Expo = 0.9  
Units: Dmnl

Cal Her Marij = 0.2  
Units: Dmnl

Cal Initiation Coc = 0.008  
Units: Dmnl

Cal Initiation Her = 0.00795  
Units: Dmnl

Cal leg Coc = 0.307  
Units: Dmnl

Cal Leg Her = 0.6  
Units: Dmnl

Cal Price Her = 0.5  
Units: Dmnl

Cal Relapse Coc = 3.006  
Units: Dmnl

Cal Relapse Her = 2.24  
Units: Dmnl

Cal Safety Coc = 0.6582  
Units: Dmnl

Cal Safety Her = 0.7545  
Units: Dmnl

Crack Frac PMUs = PMUs of Crack / Past Month Users  
Units: Dmnl

Eff Saturat Init All = Eff Saturat Init All Table (Never Frac Potl Users)  
Units: Dmnl

Eff Saturat Init C = Eff Saturat Init C Table (Never Frac Potl Users C)  
Units: Dmnl

Effect of Prevention = IF THEN ELSE (Year > 2012, IF THEN ELSE (Prevention Switch = 2, 0.75, 1), 1)  
Units: Dmnl

Ever Use Prev = Ever Users / Target Population  
Units: Dmnl
Ever Users = Not Past Yr Users + Past Year Users  
Units: People

Ever Users Prev Pct = 100 * Ever Use Prev  
Units: Dmnl

Exposure Ratio = MIN (2, (Past Mo Use Prev / PMU Prev 76) ^ 0.31)  
Units: Dmnl

HU Sw to Heroin Rate = MAX (0.2 * Crack Frac PMUs ^ 0.8, STEP (0.005, 2001))  
Units: Dmnl

Init to C Rate Pct = Initiation to Heroin Rate 1 * 100  
Units: Dmnl

Init to P Rate Pct = Initiation to Cocaine rate 1 * 100  
Units: Dmnl

Initiation to Cocaine rate 1 = Cal Initiation Coc * (Marij Prev Ratio ^ Cal Coc Marij) * (Exposure Ratio ^ Cal Coc Expo) * (Price Ratio Coc ^ (-0.2)) * (Pcvd Safety Ratio ^ 0.75) * (Pcvd Legality Ratio ^ Cal leg Coc) * (Eff Saturat Init All) * Effect of Prevention  
Units: Dmnl

Initiation to Heroin Rate 1 = MIN (Max Init to C Rate, Cal Initiation Her * (Crack Frac PMUs ^ 1) * (Marij Prev Ratio ^ Cal Her Marij) * (Exposure Ratio ^ Cal Her Expo) * (Price Ratio Her ^ (- Cal Price Her)) * (Pcvd Safety Ratio ^ 0.72) * (Pcvd Legality Ratio ^ Cal Leg Her) * Eff Saturat Init All * Eff Saturat Init C  
* Effect of Prevention  
Units: Dmnl

LU Sw to Heroin Rate = MAX (0.1 * Crack Frac PMUs, STEP (0.005, 2001))  
Units: Dmnl

LUC Abstain Rate 1 = MIN (12, Cal Abstain Coc * (Marij Prev Ratio ^ (- Cal Coc Marij)) * (Exposure Ratio ^ (- Cal Coc Expo)) * (Price Ratio Coc ^ 0.2) * (Pcvd Safety Ratio ^ (- Cal Safety Coc)) * (Pcvd Legality Ratio ^ (- Cal leg Coc)))  
Units: Dmnl

LUH Abstain Rate 1 = MIN (12, Cal Abstain Her * (Marij Prev Ratio ^ (- Cal Her Marij)) * (Exposure Ratio ^ (- Cal Her Expo)) * (Price Ratio Her ^ 0.5) * (Pcvd Safety Ratio ^ (- Cal Safety Her)) * (Pcvd Legality Ratio ^ (- Cal Leg Her)))  
Units: Dmnl

Marij Prev Ratio = (NHS PMo Marij Prev / NHS PMo Marij) * Marijuana Multiplier  
Units: Dmnl

Max Init to C Rate = 0.1  
Units: Dmnl
Past Mo HUs = Past Mo Heavy Heroin + Past Mo Heavy Cocaine  
Units: People

Past Mo Use Prev = Past Month Users / Target Population  
Units: Dmnl

Past Mo Use Prev Pct = 100 * Past Mo Use Prev  
Units: Dmnl

Past Month Users = Past Mo HUs + Past Mo LUs  
Units: People

Past Year Users = Past Year NPM Users + Past Month Users  
Units: People

Past Yr Use Prev = Past Year Users / Target Population  
Units: Dmnl

Past Yr Use Prev Pct = Past Yr Use Prev * 100  
Units: Dmnl

PMHU Prev = Past Mo HUs / Target Population  
Units: Dmnl

PMHU Prev Pct = PMHU Prev * 100  
Units: Dmnl

PMU Prev 76 = NHS Past Mo Prev 76 / Aggreg Rept Rate 01  
Units: People/Year

Prevention Switch = 1  
Units: Dmnl

Price Ratio Coc = Price pureGm Cocaine / Price PureGm Coc 01  
Units: Dmnl

Price Ratio Her = Price pureGm Heroin / Price Pure Her 01  
Units: Dmnl

Units: Dmnl

PYLUH Relapse Rate 1 = Cal Relapse Her * ( Marij Prev Ratio ^ Cal Her Marij ) * ( Exposure Ratio ^ Cal Her Expo ) * ( Price Ratio Her ^ (-0.5) ) * ( Pcvd Safety Ratio ^ Cal Safety Her ) * ( Pcvd Legality Ratio ^ Cal Leg Her )  
Units: Dmnl
Target Population = Target Pop Table (Year)
Units: People

******************************************************************************
.Reporting Rate
******************************************************************************

Aggreg Rept Rate 01 = LUC Rept Rate Norm * (1 - HU Fraction 01) + HUC Rept Rate Norm
* HU Fraction 01
Units: Dmnl

Cal Rel Eff PL NPYLU = 0.4
Units: Dmnl

Cal Rel Eff PL PMLU = 1.5
Units: Dmnl

Cal Rel Eff PL PYNPMLU = 0.2
Units: Dmnl

Cal Rel Sens HU Rept PL = 0.9
Units: Dmnl

Cal Rel Sens HU Rept PL 2 = 0.9
Units: Dmnl

Coc past year user 2001 = 0.011
Units: Dmnl

Cocaine ever user prev 01 = 0.034
Units: Dmnl

Ef PL NPYLU Rept = Pcvd Legality Ratio ^ Cal Rel Eff PL NPYLU
Units: Dmnl

Eff PL PMLU Rept = Pcvd Legality Ratio ^ Cal Rel Eff PL PMLU
Units: Dmnl

Eff PL PYNPMLU Rept = Pcvd Legality Ratio ^ Cal Rel Eff PL PYNPMLU
Units: Dmnl

EU Prev 76 = Cocaine ever user prev 01 / Aggreg Rept Rate 01
Units: Dmnl

HU Fraction 01 = 0.18
Units: Dmnl

HUC Rept Rate Norm = 0.8
Units: Dmnl
HUH Rept Rate Norm = 0.7977
   Units: Dmnl

LUC Rept Rate Norm = 0.7
   Units: Dmnl

LUH Rept Rate Norm = 0.6242
   Units: Dmnl

Max UC Rept Rate = 0.95
   Units: Dmnl

Max UH Rept Rate = 0.9
   Units: Dmnl

NPY HUC Rept Rate = MIN ( Max UC Rept Rate , HUC Rept Rate Norm * Ef PL NPYLU Rept ^ Cal Rel Sens HU Rept PL )
   Units: Dmnl

NPY HUH Rept Rate = MIN ( Max UH Rept Rate , HUH Rept Rate Norm * Ef PL NPYLU Rept ^ Cal Rel Sens HU Rept PL 2 )
   Units: Dmnl

NPY LUC Rept Rate = MIN ( Max UC Rept Rate , LUC Rept Rate Norm * Ef PL NPYLU Rept )
   Units: Dmnl

NPY LUH Rept Rate = MIN ( Max UH Rept Rate , LUH Rept Rate Norm * Ef PL NPYLU Rept )
   Units: Dmnl

Pcvd Legality Ratio = MIN ( 2, Perceived Arrest Ratio ^ ( - Cal Pcvd Legality Ratio ) )
   Units: Dmnl

PMHUC Rept Rate = MIN ( Max UC Rept Rate , HUC Rept Rate Norm * Eff PL PMLU Rept ^ Cal Rel Sens HU Rept PL )
   Units: Dmnl

PMHUH Rept Rate = MIN ( Max UH Rept Rate , HUH Rept Rate Norm * Eff PL PMLU Rept ^ Cal Rel Sens HU Rept PL 2 )
   Units: Dmnl

PMLUC Rept Rate = MIN ( Max UC Rept Rate , LUC Rept Rate Norm * Eff PL PMLU Rept )
   Units: Dmnl

PMLUH Rept Rate = MIN ( Max UH Rept Rate , LUH Rept Rate Norm * Eff PL PMLU Rept )
   Units: Dmnl
PYNPM HUC Rept Rate = MIN (Max UC Rept Rate, HUC Rept Rate Norm * Eff PL
PYNPMLU Rept ^ Cal Rel Sens HU Rept PL)
Units: Dmnl

PYNPM HUH Rept Rate = MIN (Max UH Rept Rate, HUH Rept Rate Norm * Eff PL
PYNPMLU Rept ^ Cal Rel Sens HU Rept PL 2)
Units: Dmnl

PYNPM LUC Rept Rate = MIN (Max UC Rept Rate, LUC Rept Rate Norm * Eff PL
PYNPMLU Rept)
Units: Dmnl

PYNPM LUH Rpt Rate = MIN (Max UH Rept Rate, LUH Rept Rate Norm * Eff PL
PYNPMLU Rept)
Units: Dmnl

PYU Prev 76 = Coc past year user 2001 / Aggreg Rept Rate 01
Units: Dmnl

Calibration VPD File
Arrests CocHer|Arrests CocHer/0.0001405
PY COC REP PREV|PY COC REP
PREV/196.5
Reptd PMUC Prev|Reptd PMUC
PREV/2088.9
Reptd EUC Prev|Reptd EUC Prev/237
Purity her|Purity her/14.79
Purity/Purity/14.34
Reptd PYUC prev|Reptd PYUC prev/413
PM Coc Rep Prv|PM Coc Rep Prv/508.5
NPY COC REP PREV|NPY COC REP
PREV/64
Seizures her|Seizures her/0.00261
Seizures of Cocaine|Seizures/0.00089
Price PureGm Cocaine|Price pureGm/.111
Price pureGm Heroin|Price pureGm her/0.0057

Calibration VOC File
:OPTIMIZER=Powell
:Sensitivity=Off
:Multiple_Start=Off
:Random_Number=Default
:Output_Level=On
:Trace=Off
:Max_Iterations=1000
:Sims_Max=100000
:Restart_Max=0

:Pass_Limit=2
:Fractional_Tolerance=0.003
:Tolerance_Multiplier=21
:Absolute_Tolerance=1
:Scale.Absolute=1
:Vector_Points=25
0.3<=LUH Rept Rate Norm<=0.7
0.3<=LUC Rept Rate Norm<=0.7
0.2<=HUC Rept Rate Norm<=0.8
0.2<=HUC Rept Rate Norm<=0.8
0.1<=Cal Abstain Coc<=6
0.1<=Cal Abstain Her<=6
0.001<=Cal Initiation Coc<=0.008
0.001<=Cal Initiation Her<=.8
3<=Cal Relapse Coc<=6
0.1<=Cal Relapse Her<=4
0.2<=NPY LUC Relapse Rate<=0.8
0.2<=NPY HUC Relapse Rate<=0.8
0.2<=NPY LUH Relapse Rate<=0.8
0.2<=NPY HUP Relapse Rate<=0.8
30000<=Cal Initial PMO Cocaine Heavy
Users<=120000
180000<=Cal Initial PMO Cocaine Light
User<=220000
12000<=Cal Initial PMO Heroin Heavy
Users<=80000
5000<=Cal Initial PMO Heroin Light
Users<=50000

71
0 <= Cal Arrests Cocaine Heavy Users Poss <= 0.01
0 <= Cal Arrests Cocaine Heavy Users Sales <= 0.1
0 <= Cal Arrests Cocaine Light Users Poss <= 0.01
0 <= Cal Arrests Cocaine Light Users Sales <= 0.1
0 <= Cal Arrests Heroin Heavy Users Poss <= 0.01
0 <= Cal Arrests Heroin Heavy Users Sales <= 0.1
0 <= Cal Arrests Heroin Light Users Poss <= 0.01
0 <= Cal Arrests Heroin Light Users Sales <= 0.1
0 <= Cal Coc Expo <= 0.9
0 <= Cal Coc Marij <= 0.9
0 <= Cal Her Expo <= 0.9
0 <= Cal Her Marij <= 0.9
0 <= Cal LUH Escalation Rate <= 0.3
0 <= Cal LUC Escalation Rate <= 0.3
6 <= Cal Price Coc Baseline <= 8
6 <= Cal Price Her Baseline <= 8
0.2 <= Cal leg Coc <= 1.5
0.6 <= Cal Leg Her <= 0.9
0.2 <= Cal Safety Coc <= 0.8
0.2 <= Cal Safety Her <= 0.8
0.4 <= Cal Rel Eff PL NPYLU <= 0.9
0.4 <= Cal Rel Eff PL PMLU <= 1.5
0.2 <= Cal Rel Eff PL PYNPMLU <= 0.7
0.2 <= Cal Rel Sens HU Rept PL <= 0.9
0.2 <= Cal Rel Sens HU Rept PL 2 <= 0.9
0.3 <= Cal Pvcd Legality Ratio <= 0.8
0.5 <= Cal Price Her <= 2
0.8 <= Cal Pvcd Safety Ratio <= 2

Calibration results

LUH Rept Rate Norm = 0.62568
LUC Rept Rate Norm = 0.7
HUHU Rept Rate Norm = 0.796696
HUC Rept Rate Norm = 0.8
Cal Abstain Coc = 2.94186
Cal Abstain Her = 2.52532
Cal Initiation Coc = 0.008
Cal Initiation Her = 0.00795
Cal Relapse Coc = 3.006
Cal Relapse Her = 2.24489

NPY LUC Relapse Rate = 0.7987
NPY HUC Relapse Rate = 0.2
NPY LUH Relapse Rate = 0.2
NPY HUP Relapse Rate = 0.455671
Cal Initial PMO Cocaine Heavy Users = 118355
Cal Initial PMO Cocaine Light Users = 220000
Cal Initial PMO Heroin Heavy Users = 69000
Cal Initial PMO Heroin Light Users = 24641.4
Cal Arrests Cocaine Heavy Users Poss = 0.01
Cal Arrests Cocaine Heavy Users Sales = 0.1
Cal Arrests Cocaine Light Users Poss = 0.00641863
Cal Arrests Cocaine Light Users Sales = 0.0246
Cal Arrests Heroin Heavy Users Poss = 0.01
Cal Arrests Heroin Heavy Users Sales = 0.1
Cal Arrests Heroin Light Users Sales = 0.0585079
Cal Arrests Heroin Light Users Poss = 0.00582502
Cal Coc Expo = 0.4
Cal Coc Marij = 0.390178
Cal Her Expo = 0.9
Cal Her Marij = 0.2
Cal LUH Escalation Rate = 0.0521361
Cal LUC Escalation Rate = 0.0735
Cal Price Coc Baseline = 7.19
Cal Price Her Baseline = 7.54613
Cal leg Coc = 0.291205
Cal Leg Her = 0.6
Cal Safety Coc = 0.66162
Cal Safety Her = 0.8
Cal Rel Eff PL NPYLU = 0.4
Cal Rel Eff PL PMLU = 1.5
Cal Rel Eff PL PYNPMLU = 0.2
Cal Rel Sens HU Rept PL = 0.9
Cal Rel Sens HU Rept PL 2 = 0.9
Cal Pvcd Legality Ratio = 0.8
Cal Price Her = 0.5
*Cal Pvcd Safety Ratio = 0.8
Simulations = 3614
Pass = 3
Payoff = -388.526