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A System Dynamics Model of Crime

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Abstract

In this paper we explore externalities associated with crime escalation. In particular, we look into positive feedbacks resulting from individuals' decisions to engage in illegitimate behavior. As the perceived probability of being punished for such illegal undertakings diminishes, crime becomes more appealing to individuals, and people's propensity to commit crime increases. As more crimes are committed, the ability of the legal system to cope with them diminishes. Thus, the probability of being punished falls, and crime becomes even more appealing to individuals. We see that crime levels are not controlled solely by public resources spent on deterrence, but by the characteristics of the criminal justice system. It is possible that exogenous crime shocks in a societal group can temporarily overwhelm the legal system, leading to even higher crime levels in the long run. Similarly, sharp and temporary increases in police resources could have little effect on overall crime rates because overloading effects in the legal system momentarily reduce the probability of being punished.

Key words: crime, law enforcement, justice administration.

I. Introduction and Statement of the Problem

Crime[1] threatens the fabric of society. It endangers life and personal property, and it leads to an increasing deterioration in the quality of life. Crime is costly[2]. Economic resources have to be devoted to prevent it, repress it, and mend its effects upon people and things. Moreover, crime imposes a heavy toll on businesses, which must invest in security measures to protect their assets. Crime chases away capital by rendering potential returns on business investments highly uncertain. It, thus, in a dreadful vicious circle, undermines the governments' main sources of revenues and, hence, its ability to fight and contain it.

It is, hence, desirable, from a societal and individual standpoint, to reduce crime levels. By doing so, firms and governments will have more disposable resources to improve welfare.

Reducing rampant crime rates is not easy. Crime is a puzzling phenomenon. Its understanding, let alone its control, requires a multidimensional approach (both theoretical and methodological) because its products -more theft, more homicide, more rapes- are the results of a complex system. Such complex social systems encompass many variables interacting non-linearly through multiple, possibly lagged, feedback loops. Policy makers may find it difficult to react to such complexity. As indicated by Forrester (1969: 9-10):

> In the complex system the cause of a difficulty may lie far back in time from the symptoms, or in a completely different and remote part of the system. In fact, causes are usually found, not in prior events, but in the structure and policies of the system... Conditioned by our training in simple systems, we apply the same intuition to complex systems and are led into error. As a result we treat symptoms, not causes. The outcome lies between ineffective and detrimental... If the attempted solution intensifies the problem, wrongly attributed to another source, the organization likely will redouble its "corrective" action. A destructive spiral becomes established.

Policy makers, and we, in general, tend to treat complex systems as if they were composed of a single cause and a single effect. We typically try to mitigate symptoms that appear to be most prominent. Such behavior is understandable. Many of the systems we deal with in our everyday life do reflect a close connection between a cause and an effect. But such "open-loop thinking" often triggers unexpected and counterintuitive responses from the system. For instance (Sterman, 2000:9), "...road building programs designed to reduce congestion have increased traffic, delays, and pollution." Similarly (Sterman

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[1] In this document we, in general, refer to ordinary crime. This includes instances such as offenses against life or physical well being (homicide and assault), transgressions against property (theft, robbery, fraud), and transgressions against sexual sovereignty (rape).

[2] In Colombia, for instance, crime-related costs amount to the equivalent of 13% of GNP.

2000:9), "...deregulation of the US Savings and Loan industry, designed to save the industry from financial problems, led to a wave of speculation followed by collapse, at a cost to taxpayers in the hundreds of billions of dollars". As another example (Sterman, 2000:9), "the US Government's war on drugs....with a cost in the billions, has had only a small impact on cocaine cultivation, production, or smuggling."

Open-loop thinking results in "policy resistance": despite well-intended efforts, outcomes do not change as desired. Such policy resistance is often caused by our inability to understand whole systems and by our tendency to focus on single events and their correction. Systems, complex systems, behave with unexpected dynamics which (Meadows 1982: 98-108): "....often lead to policy resistance, the tendency for interventions to be delayed, diluted, or defeated by the response of the system to the intervention itself."

Policies for reducing crime are at the forefront of the political agenda. But it appears that, in dealing with such a complex system, open-loop thinking prevails: "More crime.....more police." Laws are passed and policies implemented, but despite such efforts, crime in many parts of the world keeps escalating inexorably[3].

2. A brief review of some literature

The work of Fleisher (1966), Becker (1968), and others set the stage for analyzing crime from a rational choice perspective. This viewpoint presents individuals rationally deciding whether or not to take on criminal activities by comparing its returns with those of legitimate work. From this perspective, crime deterrence is plausible by means of more certain and harsher punishment (i.e. by reducing the expected net utility of a potential criminal). Fleisher (1966) studied the effect of income upon the individual decision of engaging in criminal activities. He found that both, the income of criminals and their victims, have an effect upon an individual's decision to commit crimes. Thus, most economic literature portraying the rational model of crime (e.g., Ehrlich, 1981, 1996) will portray a person's decision to engage in illegitimate behavior as determined by:

w_i: The expected payoff per offense

c_i: The cost incurred to acquire an illegitimate payoff w_i

w_l: The payoff from alternative legitimate activities

p_i: The probability of being arrested and convicted

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[3] In Costa Rica, for instance, crime grew exponentially at an average 9.7% per year between 1990 and 1994, and in Nicaragua, for the same period the growth rate was 8.4% per year on average.[3] In Costa Rica opinion polls regularly place "insecurity" before many other important issues such as debt reduction, inflation, or the quality of public services. This occurs despite incarceration rates in this country growing threefold in the last decade (from approximately 100 people per 100 000 inhabitants to about 300 inmates per 100 000 people.

f_i: The penalty if convicted

Thus, in the traditional economic literature on crime, an individual would engage in illegitimate activities if the net return per offense, Π_I, is positive, where

$$\Pi_i = w_i - c_i - w_l - p_i f_i \qquad (1)$$

$$\Pi_i > 0$$

Risk preferences, moral values, and the individual's proclivity for violent behavior can also be incorporated into these analyses. Ehrlich (1996) assumes, for simplicity, that individuals are risk neutral and their moral stances can be modeled, mainly for simplicity and brevity, as constant. If so, individuals would not engage in illegitimate activities when $\Pi_i > 0$, but when it exceeds some threshold "moral" level m ($\Pi_i > m$).

It becomes evident that no factor in equation (1) is independent of the others. As exposed by Fleisher (1966), agents with low incomes might perceive having little to loose from legal punishment, thus rendering even harsh punishments ineffective. Likewise, the perceived income of a potential victim might influence an agent's decision to become a criminal by increasing the criminal's perceived net utility of such a decision (Fleisher, 1966: 120):

> The principal theoretical reason for believing that low income increases the tendency to commit crime is that it raises the relative cost of engaging in legitimate activity. In the first place, youngsters probably view their families' income as an index of their own long-run legitimate earning possibilities. Thus, so long as there is not substantial positive covariation between the expected returns to legitimate and illegitimate activity, individuals with low incomes (or whose parents have low incomes) probably expect relatively large payoffs for committing delinquent acts. To such individuals, the probable cost of getting caught is relatively low, since because they view their legitimate lifetime earning prospects dismally they may expect to lose relatively little earning potential by acquiring criminal records; furthermore if legitimate earnings are low, the opportunity cost of time actually spent in delinquent activity, or in jail, is also low.

Hence, w_i, c_i, *and* w_l, in particular, will be related to a myriad of macroeconomic conditions[4]. Many studies explore correlates of crime with income, income distribution, education, growth of economic activity, and the like. Ehrlich (1973) for instance, found that higher incomes could be positively correlated with higher rates of murders, assaults, and crimes against property. He also found that income inequality within a community was positively correlated with higher crime rates. Other studies explored the effects of unemployment, education (Usher, 1993), and other economic conditions. The work of Becker (1968) and subsequent work of Ehrlich (1973, 1975) was

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[4] The term $p_i f_i$ is also related to such macroecnomic conditions, particularly through the availability of funds for maintaining strong police and justice systems.

also extended to evaluate deterrence through different levels of punishment and law enforcement. Ehrlich (1996) found that the probability of being captured and punished had deterrent effects for different crimes. Individuals who evaluate the possibility of committing crimes factor in such probability before making a choice. Thus, this literature emphasizes that changes in the expected punishment will have an effect in criminal behavior.

Though such theoretical conclusions appear strong and sound, many studies show empirical inconsistencies. Cameron (1988), for instance, reviewed several studies that tried to determine whether the number of police (or, in general, resources to apprehend and deter) has an effect upon crime. None of the studies finds a significantly negative relationship (and some find a positive one). Levitt (1997) tries to iron out these inconsistencies. By using the convenient fact that during electoral cycles net numbers of police are changed, he is able to estimate the effect of police on crime finding that increases in police "reduce violent crime, but have a smaller impact on property crime." Other work address these contradictions by refining the definitions of the main constructs involved. Levitt (1995), for instance, argues that a finer distinction must be made between deterrence and incapacitation. Deterrence refers to the effect that higher probabilities of apprehension and punishment have on the decision of a rational agent to commit crimes. Incapacitation refers to actually putting offenders out of circulation (thus precluding them from perpetrating more crimes).

In general, however, despite these subtle variable breakdowns, and despite ingenious econometric procedures to isolate the effects of the variable from measurement error, the literature still presents contradictory results. One puzzle, which this literature does not explain adequately, is the huge differences in crime levels that can be found across regions, even regions with similar economic conditions. Similarly, the static model of crime is unable to predict longitudinal variations in crime rates. Some researchers assert that (Glaeser et al. 1996: 507): "The most puzzling aspect of crime is not its overall level nor the relationships between it and either deterrence or economic opportunity. Rather.... we believe that the most intriguing aspect of crime is its astoundingly high variance across time and space." Beckerian models and its successors, which stressed the optimizing behavior of agents with rational expectations and lead to policy implications focused on deterrence, need to be expanded and complemented. Though this literature provided rich insights, it left many issues unanswered. Some studies have started addressing issues that go beyond economic conditions and deterrence and deal with intertemporal differences and to develop models to explain differences across space (Glaeser et al., 1996).

Several economic models describe social interactions among criminals and use it as an explanatory variable to understand differences in crime rates across space. These models start uncovering different feedback effects that were frequently overlooked in the literature. For instance, Andreoni (1995) explores a reduced form of Ehrlich's (1973) model and finds that higher penalties could indirectly increase crime rates by reducing the probability of

conviction[5]. Sah (1991), Murphy et al. (1993), and Gaviria (2000) add dynamic assumptions to the incentive problem posited in most of the literature. Gaviria (2000), for example, posits "a collage of possible explanations" in using positive return mechanisms to study crime in Colombia which includes: the crowding effects that can be created by law enforcement (which could lead to higher incidence of crime), the possibility of exogenous shocks leading crime in a community to a different equilibrium, and social interactions among criminals which create learning dynamics and technological spillovers. Sah (1991) models the individual's choice of committing a crime as influenced by his own perception of the probability of being punished. Such perceptions are created endogenously, through environmental influences and persist over time. In Sah's (1991: 1292) model, "the current crime participation rate will be lower if apprehension and punishment have persistently been more efficacious in the past" and "...given past variables, current crime participation rates may be rather insensitive to current policy variables."

In this paper we explore, using system dynamics, positive returns associated to criminal activities. We closely follow the dynamic relationships explored by Sah (1991) and others. In particular, we want to determine whether the overloading of legal activities (through event-oriented law enforcement efforts) can lead to increases in crime rates. In addition to this, we will explore whether an increase in criminal activities due to exogenous shocks might lead to a different equilibrium. We first attempt to create a baseline model capable of rendering steady state behavior and then explore diverse policy implications.

Our system dynamics approach easily allows us to extend many of the insights revealed in the above literature in several ways. First, the government response is endogenized by including resource constraints and delays in coming up to speed of police forces. Second, Sah (1991) assumes, for simplicity, that punished criminals return to the population after every period and, again and again, make the choice of becoming criminals or not. In our model we include incarceration. Hence, criminals, if caught and punished, remain outside the criminal population at large for several periods (in accordance with an average severity of punishment). We believe our model has the advantage of allowing to dynamically test a justice administration system's response to exogenous shocks. In particular, it allows for studying effects which are tough to identify from sets of static structural equations; such as the effects of legal system overloading.

3. A generic model

Here we present a generic and preliminary system dynamics model of justice administration. Our model draws heavily from similar system dynamics studies, particularly the work of Shaffer (1976). We try, however, to establish a closer parallelism

[5] Such reduction occurs through what Andreoni (1995) terms "avoidance" and "reasonable doubt" effects: ...If juries, like criminals, have a forecast of likely penalties, then as the expected penalty rises, the cost of an incorrect conviction also rises. This means the juror's threshold level of reasonable doubt will rise as well. The effecct is to reduce the probability that a given defendant will be convicted. (Andreoni, 1995: 476-477).

to current economic literature. The model is composed of two principal sections. An abridged explanation is as follows.

In one section of the model we deal with an individual's decision to engage in illegal activities. We follow the Beckerian tradition and posit that individuals rationally optimize, and they choose to become criminals if the payoff from such activities is higher than the payoff of legitimate work. Such net payoff is influenced by the probability of being punished. In this preliminary model we assume a stock of criminal population at large. People from this stock of potential criminals will decide to engage in illegitimate activities when

$$w_i - c_i - w_l > p_i f_i$$

We assume, for simplicity, that particular combinations of w_i, c_i,and w_l, which are, presumably, the product of a set of macroeconomic conditions, generate a given crime rate. We model in detail, however, the ability of the police and justice system to deal with such crime through arrests, convictions, and incarceration. Crime, thus, becomes a test input to our model which simulates macroeconomic disturbances which could temporarily alter the relationship $w_i - c_i - w_l$. We assume that this decision is not uniform for all potential criminals, but it is, because of different risk profiles and different moral stances, a declining function of the perceived probability of punishment (the higher the perceived probability of punishment the less people will engage in criminal activities).

Many traditional Beckerian models assume that all people, in deciding whether to commit a crime or not, make a correct assessment of the actual probability of being punished or, in other words, that the probability of being punished is an exogenous parameter constant across individuals (and that these perceptions are identical to reality). These economic models assume such an assessment to be correct and homogeneous for the whole population, and that it remains constant in time. Such an assumption might not reflect reality. Empirical studies have shown that individuals' perception of the probability of being punished is much larger than the actual probability of punishment (Richard and Tittle, 1982; Carter and Hill, 1978). Moreover, the perceived probability of punishment changes over time, and it is not homogeneous across individuals (see Sah, 1991 for a discussion). In this paper we assume the perception of being actually punished is not necessarily equal to the individuals' perceived probability of punishment. We also assume that such probabilities, both actual and perceived, change over time[6].

Sah's (1991) asserts that an individual's perceived probability of punishment is endogenously determined by the information available to him. Such information is limited and available only in the individual's vicinity. Moreover, argues Sah, "an individual's current information reflects the values of r [the actual probability of punishment] in some periods of the past."

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[6] For simplicity, however, we are not modeling here different perceptions across cohorts or in different geographical settings. Such are interesting and possible extensions to this model.

Individuals have limited information to infer such probability. They mostly draw the needed information to estimate the probability of being punished by observing people in their environment (amongst whom there are people who are not criminals and people who do engage in illegal activities. Of those who are criminals some have been punished and some have not). The more individuals within the observed group successfully (in the sense of deriving large payoffs and not being punished) engage in criminal activities, the more likely the individual will lean toward committing crime. Similarly, the larger the proportion of people who have been punished for committing crimes, the less likely the individual will be inclined to engage in illicit activities. The perceived probability of being punished is likely to differ from the actual probability of being punished. The actual probability of being punished will be related to resources devoted to catching and punishing criminals, while the perceived probability of punishment is an inference the individual makes (of the actual) based on the limited information available from his surroundings.

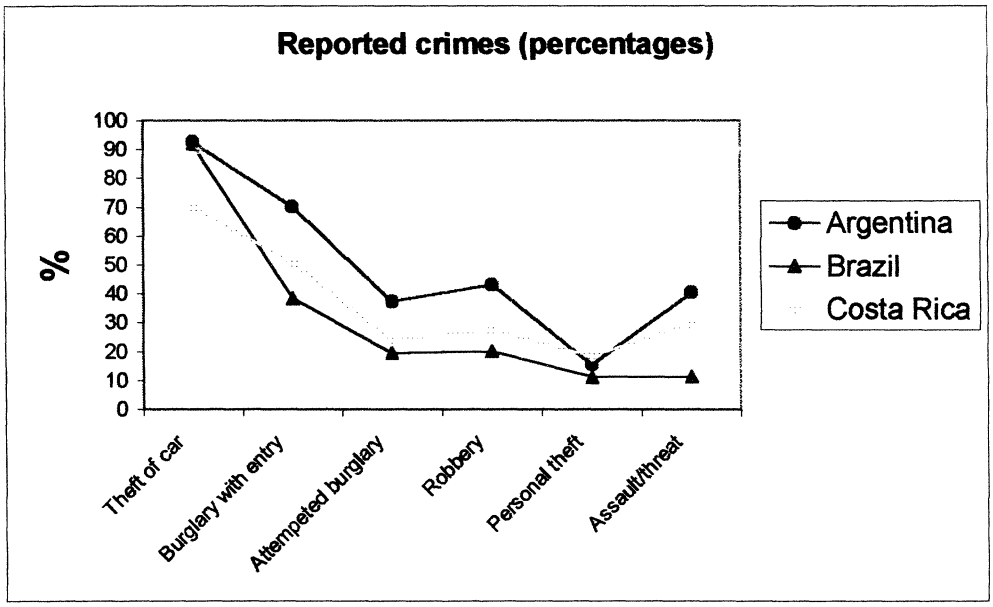
In our model we try to capture these dynamics by deriving a probability of punishment from the actual fraction of individuals in jail compared to the complete criminal population (whether in jail or not). Because individuals do not have correct and instantaneous information, the information at hand to determine such probability is distorted through a first order delay.

A second portion of the model describes the legal system. Policemen arrest people (from the criminal population at large) and bring them to trial. A number of judges determine whether arrested people should be freed or sentenced. We assume that while on trial people do not engage in more criminal behavior (i. e., remain outside the criminals at large), but are still visible to their acquaintances. The perceived probability of punishment is affected by the number of individuals who, indeed, are sentenced and imprisoned after all legal procedures are completed. It is presumed that judges well tend to dismiss more cases if their observed workload is high, and viceversa.

3.1 *Crime versus crimes reported*

Many studies show that there are significant differences between the actual crimes committed in a given setting and the number of those which are reported to the authorities. Such difference varies by type of crime. In many cases only a small portion of the actual number of crimes committed are reported to the police. Fig. 1 shows such percentages for different countries.

Fig. 1: Reported crimes in percentages for different types of crimes in three countries.



Source: Zvekic and Alvazzi del Frate, 1995

The propensity of victims to report crimes is influenced by many factors. We, in general, would predict low reporting rates if the expected net return from doing so is small. Such net return will be small if subsequent actions by police and law enforcement agencies, relative to the magnitude of the initial loss, were ineffective. Such effectiveness is closely related to the workload of the justice system. Following Shaffer (1976) we are assuming in our model that an individual's propensity to report will decrease when the judicial workload is high. This is so because the criminal justice system is critical to the impact of arrests on criminality. If such a system is overcrowded, arrested people will not be timely punished for their wrongdoing and will, thus, affect the perception (other) potential criminals might have on the probability of being punished. Gaviria (2000) describes how a crime shock in Colombia, induced during a period of time when drug cartels were fighting for supremacy, overburdened the capacity of courts. This resulted in a permanent increase in violent crime (Gaviria, 2000).

> During the late 1970s, some Colombian regions experienced an outburst of violent crime associated with the consolidation of the cocaine business. The cartels were establishing a reputation for violence while killing off their enemies outside and inside the government. This criminal wave overwhelmed a fragile justice system. Sooner than later local would-be criminals realized that both police and prosecutors were not keeping up with the increasing level of crime. This prompted many of them to enter a life in crime. As a result, kidnappings, carjackings and bank robberies skyrocketed. Eventually, the level of crime associated with drug trafficking subsided (the winners had been decided), but the crime level had already reached a critical mass – it was by then self-sustaining. Indeed, the probability of being punished (sent to prison) reached such low levels (3% for homicides

and 1% for robberies), that would be criminals were very certain that, literally, they could get away with murder.

Police efforts in arresting criminals eventually end up in a stock of pending cases. Such cases are reviewed by judges and are either dropped or brought to trial. Anecdotal evidence shows that as the backlog of pending cases increases, the probability of overworked judges dropping cases (particularly petty crime) will increase. Thus, as shown in Figure 2:
$Pending\_cases_t = Pending\ cases_{(t-1)} + dt\ (Arrests - Dropped - Trials)$

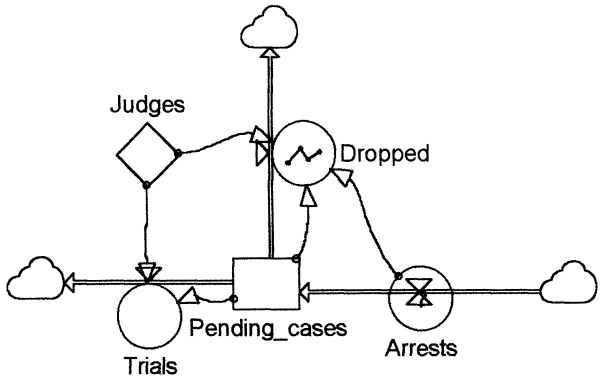


Figure 2: Basic structure of judicial system.

3.2 *Imprisonment*

The structure for sentencing criminals to prison follows a much similar structure. However, we place a static limit on the physical capacity of prisons. If prison population goes beyond this limit, the average sentence length is adjusted in order to adjust to available capacity until more capacity is built. This oversimplification is not entirely inadequate. Levitt (1996) has studied the effect of prison population size on crime rates using evidence from prison overcrowding litigation in the United States. In his paper he indicates (Levitt, 1996:323):

> Over the past 30 years, prisoners' rights groups have brought numerous civil suits alleging unconstitutional conditions in prisons. In twelve states the entire state prison system either is currently or has formerly been under court order concerning overcrowding.....Not surprisingly,....., the existence of overcrowding litigation reduced the growth rates of prison populations. For example, in the three years prior to the initial filing of litigation in the twelve states where the entire prison system eventually fell under court control, prison population growth rates outpaced the national average by 2.3 percent annually. In the three years following the filing of litigation, prisoner growth rates lagged behind the nation as a

whole by 2.5 percent a year. In the three years after a final court order was handed down, growth rates were 4.8 percent below the national average.

Anecdotal evidence suggests that additional capacity to prisons is added only when overcrowding becomes an impending problem. Were not for litigation, it is likely that prisons would remain filled over their capacity. Levitt (1996) indicates, however, that judges do not ordinarily mandate the release of prisoners, but more frequently force a ceiling which should be accomplished by whatever means the administrators of the penitentiary system see fit (i.e., building more capacity, implementing early release programs, and the like). In our model, the sentence reduction is coupled by the building of more jails. The new capacity is added three years after previous limits have been surpassed. We assume that a fraction of the prisoners who benefit from early release become recidivists.

The model is shown in Figure 3 (much detail is omitted).

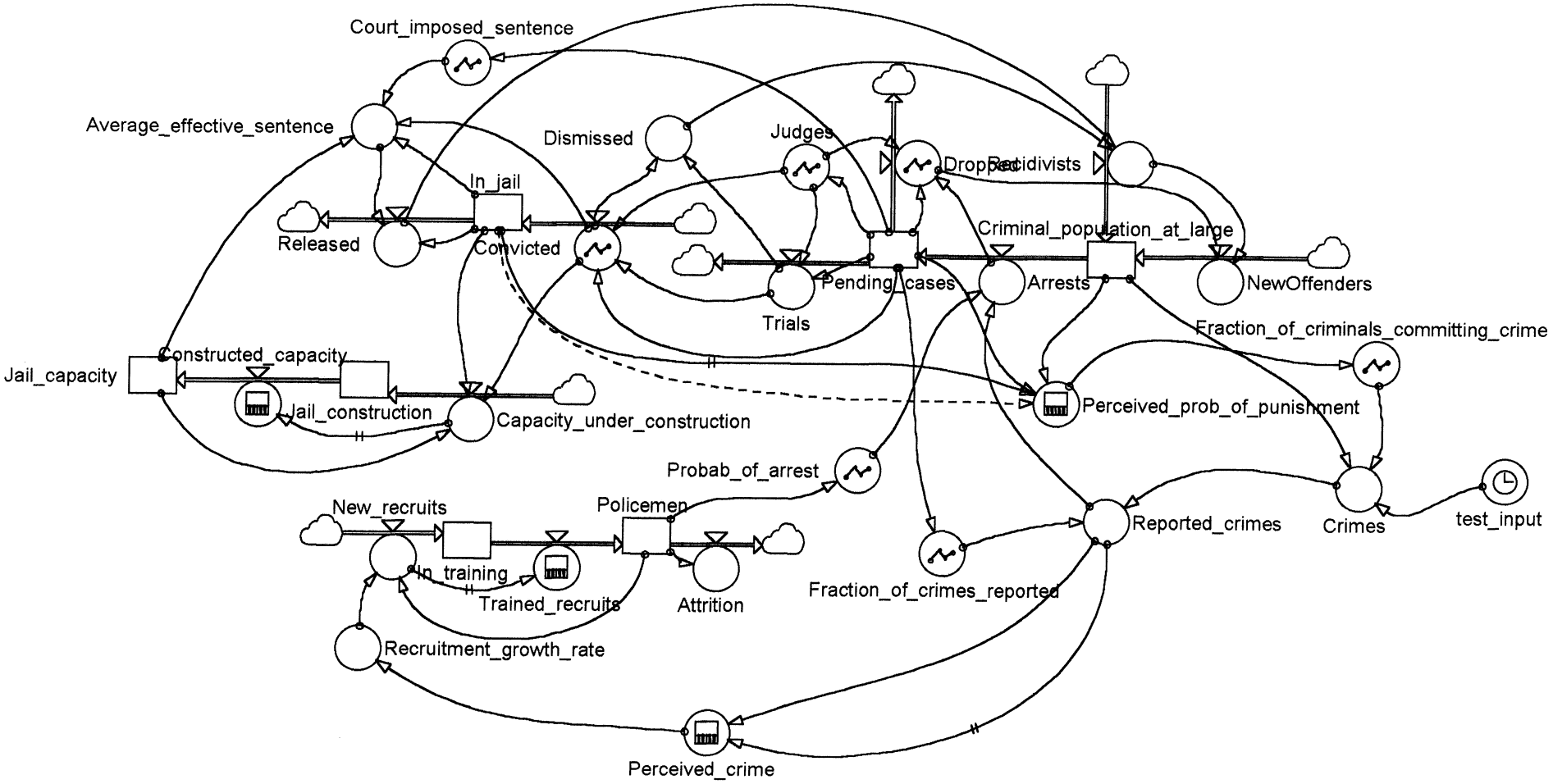


Figure 3. A model of crime dynamics.

4. Some preliminary estimates

We estimate an initial run in which the system attains and appears to remain at certain equilibrium values. In this model crime stabilizes at around 12000 cases per year as shown in Figure 4. the actual probability of punishment remains a little over 15%. In this initial run the model is setup to quickly react to prison overcrowding. Hence, additional jail capacity is constructed approximately 50 years into the simulation and a drop in average effective sentence (due to a temporary prison overcrowding when installed capacity becomes inadequate) is almost imperceptible.

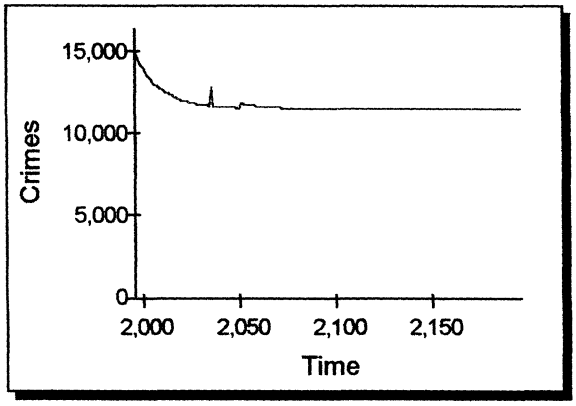


Figure 4: Crimes commited. Initial run.

A test input was thereupon introduced to examine the dynamics of the model. All features were left unaltered, but a STEP input was introduced halfway into the simulation. Under such conditions crime appears to increase slightly and to remain at higher levels, notwithstanding the additions of more law enforcement personnel, jail capacity and judges, to the system thereupon. Several years are required to return to its former crime level conditions.

A further test was introduced by incapacitating some of the functions that allowed the system to respond to such test inputs. In particular we tested the system with a constant judge capacity. Although police resources start increasing (due to pressure exerted by the "crime wave" represented by the step function), the lack of a concomitant response in the judicial system ends up in a higher long run crime rate. This can be seen in Figure 5.

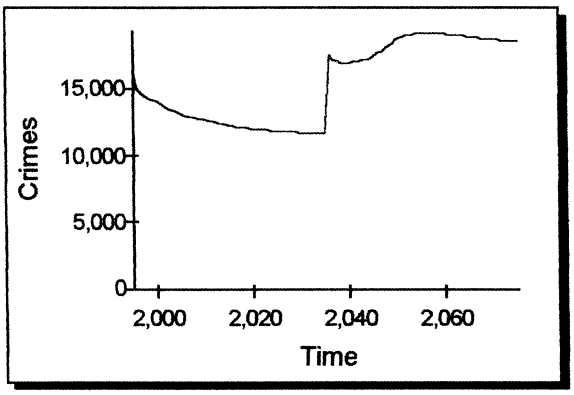


Figure 5: Crimes commited, step test input, constant judge capacity.

As can be observed in Figure 6, this new equilibrium at a higher crime rate is due solely to the inability of the judicial system to cope with arrested criminals. The number of pending cases starts growing and, despite enough jail capacity and despite a slightly higher probability of arrest, the perceived probability of punishment drops, thus resulting in more crime in the long run. Interestingly, if the law enforcement authorities react quicker to the crime escalation, the previous results are exacerbated somewhat.

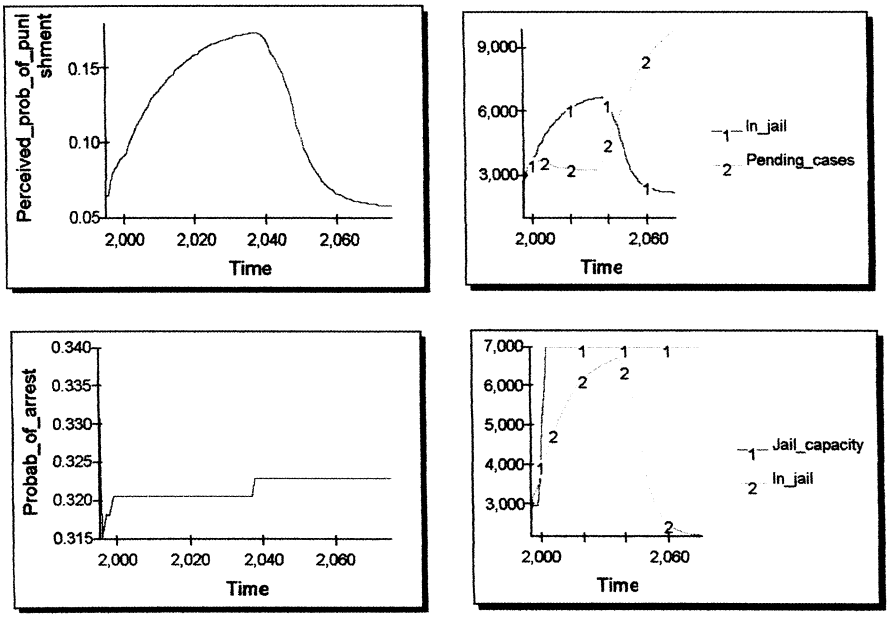


Figure 6: Constant judge capacity. Results.

5. **Conclusions**

The model here presented introduces dynamic considerations into economic crime models based on rational choice. It determines an individual's propensity to commit crimes by determining his perceived probability of punishment. The model incorporates a description of a criminal justice system. This description takes into account its apprehension capabilities, modeled through policemen available, judicial capability, modeled through an installed capacity of judges, and punishment capabilities, modeled through a given prison capacity. The model includes delays in the construction of prisons and in the recruiting and training of new policemen.

Results using this very preliminary model shows that policies entirely based on the commissioning of more police could lead to a short run decrease in the rate of growth of criminality, but they could eventually backfire through overburdening the criminal justice system. It is of particular interest to note that overcrowding of the judicial system or a temporal reduction in resources may have counterintuitive effects upon crime rate. A subsequent increase in resources will not be followed concomitantly by a decrease in crime rates. Such results have important policy implication whereas they mean that whatever action a politician takes to reduce crime will, likely, not show results within his tenure.

At this stage, the model presents the need for policy makers to coordinate resource allocation between the criminal apprehension and reprehension systems. Temporary unbalances between them have undesirable effects. The marginal return of resources devoted to apprehend may be lower than expected due to overcrowding effects of the judicial and penitentiary systems.

The paper and model presented here are only preliminary. It represents an early snapshot of an ongoing research process. We are presently refining and calibrating the model with actual data from one country in order to have more empirically- grounded results.

References

Andreoni, James. 1995. Criminal deterrence in the reduced form: a new perspective on Ehrlich's seminal study. *Economic Inquiry* **33**: 476-483.

Becker, Gary. 1968. Crime and punishment: an economic analysis. *Journal of Political Economy* 76: 169-217.

Becker, Gary. 1993. Nobel lecture: the economic way of looking at behavior. *Journal of Political Economy* 101: 385-409.

Cameron, Samuel. 1988. The economics of crime deterrence: a survey of theory and evidence. *Kyklos* **41**: 301-323.

Carter, Ronald and Kim Hill. 1978. Criminals' and noncriminals' perceptions of urban crime. *Criminology* 16: 353-371.

Ehrlich, Isaac. 1973. Participation in illegitimate activities: a theoretical and empirical investigation. *Journal of Political Economy* 81: 521-565.

Ehrlich, Isaac. 1975. The deterrent effect of capital punishment: a question of life and death. *American Economic Review 65*: 397-417.

Ehrlich, Isaac. 1981. On the usefulness of controlling individuals: an economic analysis of rehabilitation, incapacitation and deterrence. *American Economic Review* **71**: 307-322.

Ehrlich, Isaac. 1996. Crime, punishment, and the market for offenses. *Journal of Economic Perspectives* **10**: 43-67.

Fleisher, Belton M. 1966. The effect of income on delinquency. *American Economic Review* **56**: 118-137.

Forrester, Jay. 1969. Urban Dynamics. Productivity Press: Portland, Or.

Garoupa, Nuno. 2000. The economics of organized crime and optimal law enforcement. *Economic Inquiry* **38**: 278-288.

Gaviria, Alejandro. 2000. Increasing returns and the evolution of violent crime: the case of Colombia. *Journal of Development Economics* **61**: 1-25.

Glaeser, Edward L., Bruce Sacerdote and José A. Scheinkman. 1996. Crime and social interactions. The Quarterly Journal of Economics **111**: 507-548.

Levitt, Steven D. 1997. Using electoral cycles in police hiring to estimate the effect of police on crime. *The American Economic Review* 87: 270-290.

Levitt, Steven D. 1996. The effect of prison population size on crime rates: evidence from prison overcrowding litigation. The Quarterly Journal of Economics **111**: 319-51.

Meadows, Donella. 1982. Whole earth models and systems. *CoEvolution Quarterly*, Summer: 98-108.

Murphy, K., A. Shleifer and R. Vishny. 1993. Why is rent seeking so costly to growth? *American Economic Review* 83: 409-414.

Richards, Pamela and Charles Tittle. 1982. Socioeconomic status and perceptions of personal arrest probabilities. *Criminology* 20: 329-346.

Sah, Raaj K. 1991. Social osmosis and patterns of crime. *Journal of Political Economy* **99**: 1272-1295.

Shaffer, William A. 1976. Court Management and the Massachusetts Criminal Justice System. Unpublished dissertation, Massachusetts Institute of Technology.

Sterman, John. 2000. Business Dynamics: Systems Thinking and Modeling for a Complex World. Irwin/McGraw Hill: Chicago, IL.

Usher, Dan. 1993. Education as a deterrent to crime. Institute for Economic Research, Queen's University. WP # 870.

Zvekic, Ugljesa and Anna Alvazzi del Frate (editors). 1995. Criminal Victimisation in the Developing World. United Nations Interregional Crime and Justice Research Institute. Rome.