Authors
Berger, Luiz Marcelo
Borenstein, Denis
Balbinotto Neto, Giácomo

A COMPUTATIONAL METHOD APPLIED TO THE ECONOMIC ANALISYS OF CRIMINAL LAW

Luiz Marcelo Berger[A]

Denis Borenstein[B]

Giácomo Balbinotto Neto[C]

ABSTRACT

This work develops an agent-based model to study the emergent properties due to public enforcement of criminal law. In order to build a model of criminal behavior suitable to the project the economic analysis of crime is used as the basic framework, most specially Becker's (1968) seminal work, but also Shavell and Polinsky (2000), Shavell (2004), Cohen and Felson (1979) and Clarke (1995). The mainstream has been the economic analysis of law, which considers the agent as a rational decision maker. The model was implemented using NetLogo 3.1.4, a multiagent software platform (Wilensky, 1999). The simulation program provides a wide range of dynamic options making it easy to perform any kind of test in order to assess the behavior of a given criminal rule in its dynamic operation. Validation and experimental tests were performed. The resulting responses were consistent with the theoretical basis on which the model was based on.

Keywords: agent-based models, multiagent systems, economic analysis of Law, criminal Law, simulation.

JEL classification: K4; C2

[A] Phd Student, School of Management, Federal University of Rio Grande do Sul, Rua Washington Luis, 855, CEP 90010-460, Porto Alegre, RS, Brazil.

[B] Assistant Professor, School of Management, Federal University of Rio Grande do Sul, Rua Washington Luis, 855, CEP 90010-460, Porto Alegre, RS, Brazil

[C] Assistant Professor, Faculty of Economic Sciences, Federal University of Rio Grande do Sul, Av. João Pessoa, 52 sala 33-B - Centro - Porto Alegre, RS, Brazil.

> *To me the most interesting aspect of the law and economics movement has been its aspiration to place the study of law on a scientific basis, with coherent theory, precise hypotheses deduced from theory, and empirical tests of the hypotheses … Economics is the most advanced of the social sciences, and the legal system contains many parallels to and overlaps with the systems that economists have studied successfully.*
>
> *Judge Richard A. Posner, in Michael Faure and Roger Van den Bergh, eds., ESSAYS IN LAW AND ECONOMICS (1989).*

1. Introduction

This article attempts to address the crime phenomena through a computational method in order to simulate agents' behavior under the rule of law, using Becker's (1968) seminal model and, as an empirical basis, the recent Brazilian experience.

What makes the approach different, in many aspects, derives from the computational framework used to accomplish this. It attempts to address crime committing by using the computational framework to study alternatives concerning criminal behavior tackling. A computer-based system offers an interesting cost-benefit relation vis-à-vis more traditional methods of analysis, in particular, when different scenarios are subject to evaluation under a large number of interdependent variables.

The central point of economic analysis is the individual, since he makes the choice and, ultimately, the decisions. Regarding economic theory of crime, the same principle prevails: the focus is centered on the individual's decision making. However, we wish to study, through an agent-based computational model, which are the legal consequences and implications that emerge in a complex society in which individuals learn, have several behaviors relating risk and interact with each other upon which there is a legal framework that imposes penalties and where the probability of capturing the culprits is variable.

All along history, criminality has been subject to permanent and extensive research by numerous scholars from a wide diversity of specialties. One may wonder the motive behind such interest and it is certainly not a difficult task to figure out why is that so. Crime is, actually, all around. From misdemeanors to horrible felonies, when *means rea* assumes a critical meaning, people must deal with it on a daily basis.

In some societies crime turns to be almost endemic (Cooter *et al*, 1999), especially in terms of drug dealing, trafficking, organized crime, corruption, etc, whereas the social consequences - and economic ones - reach far more terrible effects than would be reasonably acceptable (Fiorentini and Peltzman, 1997).

The present model has been conceived using official criminal databases for car theft (larceny and robbery) collected in the metropolitan area of the city of Porto Alegre, which is the capital of the state of Rio Grande do Sul located in southern Brazil, in the year of 2005. Overall police reports reached 12.959 events in that period. The estimated population is close to 1.5 million people for the year of 2007.

The main purpose of the agent-based model developed in this paper is understanding the proprieties of a complex social system phenomenon, like crime, through the analysis of a computer based simulation.

This article is divided into six sections. In section two, an economic model of crime is presented. In section three the framework of the model is shown, inspired in Becker's (1968) seminal article on crime and punishment. In section four a model of artificial society in a context of multiagents system is presented. In section five an agent-based computational model architecture for criminal behavior is presented. In section six simulations and experiments derived of the model are presented and finally, in section seven, we present the final remarks about what has been done in the precedent sections.

2. Models of Economic Analysis of Criminal Law: A Short Review

The basis of the economic approach of crime is the assumption that people involved with the legal system act as rational maximazers of their utility. Since most of the time the choice of the individuals involves uncertainty – the result of a crime is not given as certain beforehand – the relevant economic theory analyzes the decision making in uncertain conditions.

Rationality, under Becker's (1976) assessment is an instrumental concept. It requires, however, the existence of objectives, although an economist, as a social scientist would not question how these objectives are made up. Only the results of these processes are relevant for economic analysis.

Assuming rationality in economics studies or when it is applied to crime, only means that people act on purpose in the search of objectives autonomaly chosen; it means, more specifically, that people prefer more to less, of the things they desire. Economists use the framework of rationality as a description of human behavior, and as a way of identifying the foreseeable reaction of the average individual that composes the group.

According to Mercuro and Medema (1997, p.58) the rational individual contrasts with the reasonable individual in what refers to the tradition of legal theory – an individual, who is socialized in the norms and conventions of a community, and whose behavior corresponds to these norms. Laws, as a consequence, should reflect these norms and conventions and therefore, be obeyed by reasonable individuals. In this way, those who engage in illegal activities (theft, kidnapping, murder, etc.) are seen as having a deviate behavior in the sense that they have violated or broke those norms and conventions. This approach poses problems in terms of computational modeling.

The idea that individuals are rational maximazers implies that they respond to the incentives provided by prices – that a consumer will consume less of a certain good if the price increases, for example, *ceteris paribus*. In this case, here exposed, fines, or jail or death penalty work as the price paid by the criminal for committing a crime.

For Mercuro and Medema (1997, p. 58 -59), within the context of law, legal rules establish prices, such as fines, community service or prison, for the engagement in several types of illegal behavior activities (fraud, smuggling, theft, murder, corruption, etc). The maximizing individuals will then compare the fringe benefits and the cost of each additional unit of illegal activity and compare it with the costs (being pondered by the probability of being detected and condemned).

As a way of systematically dealing with criminality, the economic approach to legal ruling has been subject of extensive and continuous research. As Shavell and Polinsky (2000) put it, this particular relationship has been noticed since the eighteenth century with the writings of Montesquieu, Beccaria and, most especially, Bentham. Nevertheless, and to some extent, curiously, the academia left it dormant until the late sixties when the extremely influential article of Gary Becker (1968) was made public. Ever since, an increasing number of articles have been published, making the economic approach of law an influential mainstream in the most influential academic circles of the world, most notably in America (Tullock 1969, 1974).

Becker's (1968) model (*rational criminal model - RCM*) assumes that the choice of a criminal to commit a crime is a rational behavior in which cost and benefits are compared with the uncertain result of success or going to jail. The model sees the criminal activity as an investment: taking into account the risk, a high return is expected.

Must be said, however, that several other economic models try to deal with criminal behavior: (i) time allocation model; (ii) migration model; (iii) portfolio model; (iv) principal agent model and (v) behavioral or social interaction model.

Time allocation model assumes that the individual must decide how to allocate their time between legal and criminal activities. Therefore, we have that the individual would choose to maximize the optimal allocation of time between the two activities, the legal ones and the illegal ones. Accordingly, the expected utility function of the criminal will depend on the relative gains, in legal and illegal activities. In terms of economic policy, the aim would be to find ways of discourage individuals from participating in criminal activities. Becker (1968) establishes that individuals choose how much time to allocate to work in an economic activity, be it legal or illegal, according to their preference, taking into account it's risk behavior (neutral risk, prone to risk or certain risk). He assumes that the individual decides to commit a crime if the expected utility exceeds the utility he would be able to obtain, using his time in a legal activity.

The migration model tries to explain why some individuals migrate from legal to illegal models. The decision of an individual to participate in an illegal activity will only happen after assessing the various opportunities available in the legal and illegal areas, choosing the one that maximizes his expected gain. The decision of an individual to migrate from a legal activity to a criminal one will be a function of the difference in gains of the legal activity in relation to the illegal one and the cost of migrating. The neoclassic theory of criminal migration uses the theoretical structure of the human capital to analyze the phenomena of criminal mobility and workers rotational moves between legal and illegal activities. It seeks to demonstrate how the *insights* of human capital theory can explain the patterns of mobility observed between legal and illegal activities for a given individual during his lifetime. There is a certain element of self-selection in the migration towards criminal activity since those individuals who have a higher probability of migrating are those whose benefits from migration are also higher. The neoclassical theory sees the migration of individuals from legal activities to illegal ones as a form of investment in human capital. Thus, the study of the decisions referring to migration from a legal activity to an illegal one is nothing more than the application of the human capital theory to the dislodgement of workers between these two activities, aims to maximize the well being of the individuals. The migration from legal activities to illegal ones, in the neoclassical theory, is seen as an individual spontaneous and voluntary action, which rests on the comparison between a present situation (legal market) and a future situation (illegal market) based on cost benefit. In this way, individuals migrate from legal activities, in situations in which a high return is expected, after considering all the available alternatives. Migration is affected by four main factors: (i) the gain in the legal activity of the economy – which is a direct function of the level of education, experience of the individuals in the work market; (ii) the earning expectancy in the illegal activity; (iii) the probability of success in the illegal activity, measured by the efficiency of the police and judicial institutions and (iv) pecuniary and non pecuniary costs of migration to crime, related to socioeconomic variables, such as education, morals and family habits.

According to Carrera-Fernandez and Pereira (2001), the main conclusions extracted from the migration models are that individuals tend to migrate to crime when the difference between the present expected earnings of legal and illegal activities and the lower the cost of migrating. In the migration models, variables deal with attitudes in relation to the future, as well as different perspectives along the timeline of the agents. Therefore, the higher the rates of timeless discount of the agents, the migration to criminality is most probable.

In the portfolio model individuals must choose how to allocate their time between legal activities (without risk) and criminal activities (risky). Criminal activities provide an expected high return but also a high risk (being caught and going to jail). Legal activities, on the other hand, furnish a low return but also a low risk as well.

The principal-agent model shows that dissuasion from criminality does not come from the mere police action, but from the active presence of the community (citizens) to report the occurrences and collaborate with police investigation.

The behavioral or social interaction model admits that individuals are capable of criminal activity through social interaction. Such models facilitate deeper analysis regarding the differentials of criminality indexes among regions. In the next section we will deal with this question. This particular remark is also addressed within the context of the architecture of the agent-based model and how the rules of individual behavior are conceived in order to design an artificial society (Axtell and Epstein, 1996).

3. Framework of the Model

The model seeks to establish dynamically the relationship between micro and macroeconomic variables. Each singular behavior of any agent within the environmental framework subject to analysis will have an associated cost of transaction. Agents' interaction alters randomly their conditions during simulation process and, therefore, the overall macroeconomic performance.

The basic strategy used by agents when engaging (or not) in criminal activity within a given context is Becker's (1968) formulae which states formally:

$$\mathbf{g > p(f + \lambda t)} \qquad \mathbf{(1)}$$

Where:

g = gain a party obtains by engaging in harm-creating activity;

p = probability of detection;

f = fine;

t = length of the imprisonment term;

λ = disutility borne by a prisoner per unit of the imprisonment term.

In literal terms, a risk neutral agent will commit the harmful act if and only if his gain from doing so exceeds the sum of expected fine and the expected disutility of the imprisonment term.

As Becker (1968) puts it, a criminal, with the exception of a limited number of psychopaths, is assumed to react to different stimuli in a predictable ("rational") way, both with respect to returns and costs, such as in the form of expected punishment. Instead of considering criminal activity an irrational behavior associated with the

specific psychological and social status of an offender, criminality is analyzed as rational behavior under uncertainty.

4. Artificial Societies and Multiagent Systems

Social sciences are the real hard sciences, as Herbert Simon has emphasized (Axtell and Epstein, 1996). Human behavior in society poses great challenges to researchers due to the almost infinite number of variables that interact simultaneously in many given scenarios leading to complex systems. Actually, there is no simple way to decompose social phenomena in sub-processes, such as economical, cultural, demographic, spatial, etc. Simon (1962) described a complex system as one made up of a large number of parts that interact in a non-simple way. Even more important, Simon (1962) observed that the whole is more than the sum of the parts, making the emergent phenomena a desirable feature of any social simulation technique. In other words, it turns to be a difficult task to establish cause-effect patterns among micro variables and their macro consequences in a simple and intuitive way. Scheling (1978) was among the pioneers when studying segregation patterns. At that time, there was no computational resource available to make significant advances in the field of multiagent interaction.

In terms of criminal behavior, this assessment turns to be crucial, because the occurrence of criminal behavior may be triggered by numerous factors such as economic, geographical, sociological and psychological among others.

The *NetLogo* (Wilensky, 1999) multiagent application platform allows the model to simulate the behavior of variables along a time-axis in a simple way, which is useful to evaluate how a system behaves in terms of macroeconomic equilibrium.

Artificial Societies are mainly multiagent systems that hold some specific features coming from Artificial Intelligence (Russell and Norvig, 2003). *Agents* are computational systems that have some properties. They are autonomous, which means that they make their own decisions without external influences. They have social abilities that allow them to interact with other agents. They are reactive and pro-active, managing to respond to environment actions coming from other agents or the environment itself (Wooldridge, 2002). Russell and Norvig (2003) mention that intelligence is tied to rational actions. To act rational means that the agent tries to achieve a goal using the knowledge it originally has using the best-case scenario available. That means the agent perceives its surroundings whatever it may be and acts according to previous rules in order to accomplish a given goal. As mentioned previously, agents are considered rational decision makers trying always to get its objective by maximizing its marginal utility.

There are two other important characteristics worth mentioning. Agents can be deliberative or simply reactive which are different ways to interact with the systems. The former is most used when the system is designed to be in a BDI[1] (Rao and Georgeff, 1991) framework. The latter refers to an agent that simply reacts to the environment using relatively simple *IF…THEN…ELSE* logical structure. Although this concepts are very important in simulating process, the discussion over the suitability of one or another goes beyond the scope of the present work. Future works, however, should address this feature because it clearly improves the way agents' behavior is modeled.

[1] BDI is the short form of *Belief-Desire-Intention, a* computational multiagent architecture with very specific features in terms of capabilities in a given artificial society.

Nevertheless, the simulation technique used in this present model was not a BDI framework, because Netlogo 3.1.4 platform does not support it. The NetLogo (Wilensky,1999), on the other hand, allows the model to simulate the behavior of variables along a time-axis in simple way, which is useful to evaluate how a system behaves in terms of macroeconomic equilibrium.

5. The Agent Based Model Architecture for Criminal Behavior

The model is built upon three agents (or set of agents) that dynamically and randomly interact with each other and with the environment, simulating, as close as possible, real criminal events. The model is conceived as follows:

Citizen Agent – This agent represents some probable perpetrator. It must be stressed that the model does not assume prior criminal condition from the agent. That condition will be given by the simulation process and depends upon the probability distributions more suitable for the case. Therefore, the engagement in criminal activity is a *decision* the agent takes during the simulation process, depending upon the particular conditions regarding the crime committed, whereas it may be an assault, battery, rape, manslaughter, murder and so forth. The incoming data that feed the simulator parameters is modeled for each particular case, or criminal act.

Opportunity Agent – This agent represents the specific target of criminal activity that is protected by law over which the c*itizen agent* might be interested in. This agent models the specific right, protected by law, subject to simulation. In this present study, the agent is represented by vehicles once it intends to model car theft. In this particularly case, the opportunity agent is a *property belonging to another* as follows, according, for instances, to the British law regarding the subject:

"A person shall be guilty of theft if he dishonestly appropriates property belonging to another with the intention of permanently depriving the other of it."[2]

In the simulation process, this agent will represent specifically *vehicles* with a monetary value that would make it an interesting target in terms of incentive for a probable offender.

State Agent – Represents the Public authority in charge to address enforcement of criminal legal rules. The initiatives or actions taken by state agents may be not just criminal fighting through police means, but interventions in many social circles may have intense effect on criminal rates. Numerous studies (Scheinkman *et al*, 1996) associate criminal activity with environmental conditions. Moreover, social interventions such as education improvements, health care and family assistance are consistently rated as crime inhibitors (Kingston et al, 2003).

Sheinkeman *et al.* (1996) in an extensive study over criminal trends have also found out that social interactions are deeply correlated to criminal engagement. The authors cautiously stress that the most intriguing aspect of crime criminal activity is its "*astoundingly high variance across time and space*", meaning that in fact there is no simple way to understand the phenomena. On the other hand, there is no doubt that public intervention other than law enforcement through police means may reveal much

[2] **Theft Act 1968** (1968 c.60), S.1(1), United Kingdom

more effectiveness in the long term planning. Needless to say, education for example, is one factor that can make enormous differences in criminal patterns.

Figure 1 shows schematically how the agent based model has been designed. The outer circle represents the law jurisdiction, and in most cases will have direct relation with a space variable, or a boundary limit within which the criminal law has effectiveness and must be complied.

A state jurisdiction would be enforced within its borders whereas a federal ruling must be complied all along a whole country. The agents' interactions regarding the enforcement of law can be seen in the way the *citizen agent* and the *opportunity agent* are connected: an arrow representing an *actus reus*, which is a deliberate action taken by the former towards de latter through criminal means.

Over this set of *agent-action-agent* the *state agent* must take action to uphold the law, because the model assumes a criminal engagement among the first two agents. As a consequence, as should be noticed, any crime so considered may be represented by this tree agents, or set of agents. The reason for this assumption relies in the scope of the economic theory of public enforcement of law, as Shavell and Polinsky (2000) put it. In order to be a *public enforcement of law*, a *public agent* must interact with the other two agents. The *public agent* represents the public domain, which has the ultimate monopoly of law, which cannot be transferred, suppressed or ignored.

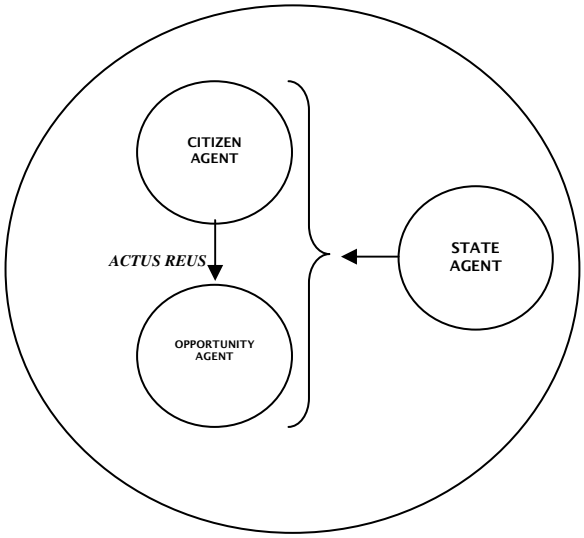


Figure 1
The Agent Based Model Architecture of Criminal Law Enforcement

Wherever a violation takes place, and the related sanction takes place as a criminal one, the state intervention is mandatory. In modern societies abiding by the rule of law, there is no such thing as private vengeance.

Yet, regarding the applicability of the model in terms of cause-effect interactions, the proposed simulation allows to study variables much like Erhlich (1996) puts it, that is, as variables in a *market-model* of offenses. As the author emphasizes this model "*builds on the assumption that offenders, as members of the human race, respond to incentives"*.

6. Simulation Experiments

Since its inception, the model attempts to keep things as simple as possible, yet flexible and powerful, to fit as many criminal scenarios as possible. Keeping that endeavor as a crucial feature of the model, the interacting agents, within the model, can be also viewed as a *set of agents.* This capability allows performing various kinds of tests, in such way that make it possible to observe the effect of public intervention in any domain.

As Shavell and Polinsky (2000) state, public enforcement of law encompasses all public agents who are in charge to uphold the law, such as inspectors, auditors, police, prosecutors, etc. All of them bear the responsibility to protect those rules chosen by society to be enforced.

The model appropriates singular transaction costs in each microeconomic level in order to study the overall consequences emerging in the macroeconomic level. The simulating experiments performed were seeking to verify and validate Becker`s (1968) seminal theory of agents' criminal behavior. As an artificial society is created by means of a multiagent computer application (Wilensky, 1999) to study the emergent phenomena, macroeconomic variables are also modeled in order to capture the outcome of agents' interactions.

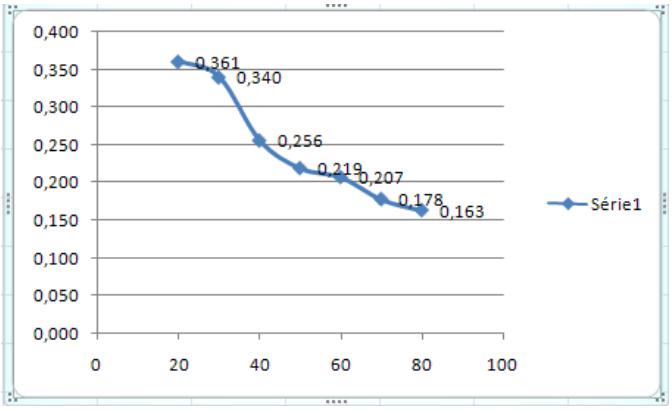
Preliminary tests were performed to establish whether the behavior of the agents in the simulation would respond according to the theoretical basis upon which it was based upon, that is, if incentives play (or not) a crucial role into agents' decision making and to what extent. Also, tests were performed in an attempt to achieve a steady state of equilibrium, where the behavior of macroeconomic variables reached some level of stability, given the incoming microeconomic parameters.

As the operational mindset of the model is organized through the economic analysis of criminal law, the incoming parameters are microeconomic data obtained in official databases. For simplicity purposes, the simulation assumes that the data is a normally distributed function N (μ, σ) where μ is the mean and σ is the standard deviation. The model, though, allows any probability distribution to be used. The functions intervals can be empirically determined, according to researcher's aim.

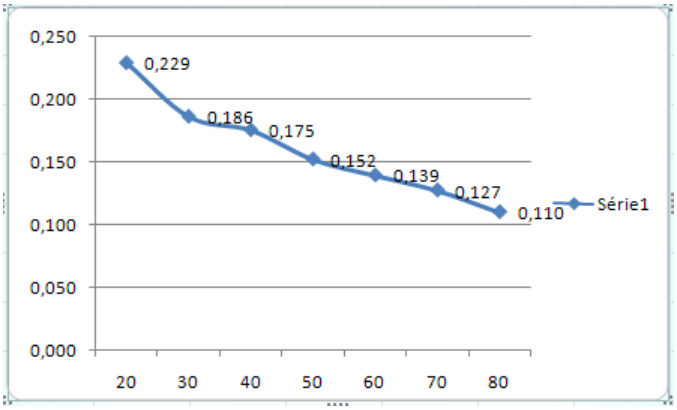
The results (figure 2) are consistent with Becker's (1968) framework, which states that an individual responds to incentives, positively and negatively, and engage in criminal activity if and only if his gain from doing so exceeds the sum of expected fine and the expected disutility of the imprisonment term, combined with the probability of detection and punishment by law enforcement officials, as given by equation **(1)**.

Experiments showed that even with different levels of incentive, the crime rate decreases proportionally when disutility due to imprisonment term and probability of punishment increases. All incoming data were obtained in Brazilian official databases concerning car theft rates in the city of Porto Alegre in the year of 2005 and the simulation results were consistent with actual crime rate data collected in the related period considered.

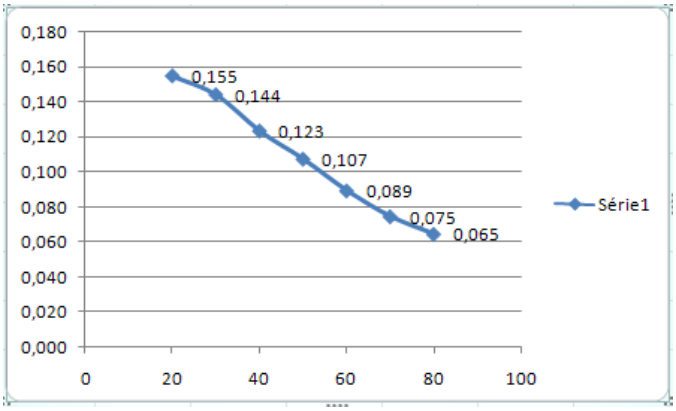
Figure 2 show the results obtained in the simulator using three degrees of agents' income in order to evaluate their behavior dynamically when facing a possible criminal event.



(a) US$ 184,44



(b) US$ 555,55



(c) US$ 1.844,44

Figure 2
Crime rates *x* probability of detection

The x-axis gives the probability of detection (and punishment) *p.* The y-axis gives the crime rates obtained with the simulation experiments. In accordance to Becker's (1968) equation **(1),** as increases *p,* crime rates decrease proportionally, making the results consistent with Becker's (1968) framework. Also, as the experiments were performed for agents with different income levels, the simulation tests show a

proportional decrease in crime rates as agents' marginal income increases, as theoretically expected. Income figures are shown in dollars, for simplicity purposes[3].

The simulator operating console is shown in figure 3 with typical NetLogo (Wilensky, 1999) features, which allow performing various kinds of experiments, particularly, simultaneous interaction among microeconomic variables and the macroeconomic outcome. All along the simulation process, the probability functions used to generate random entry data can be fully controlled.

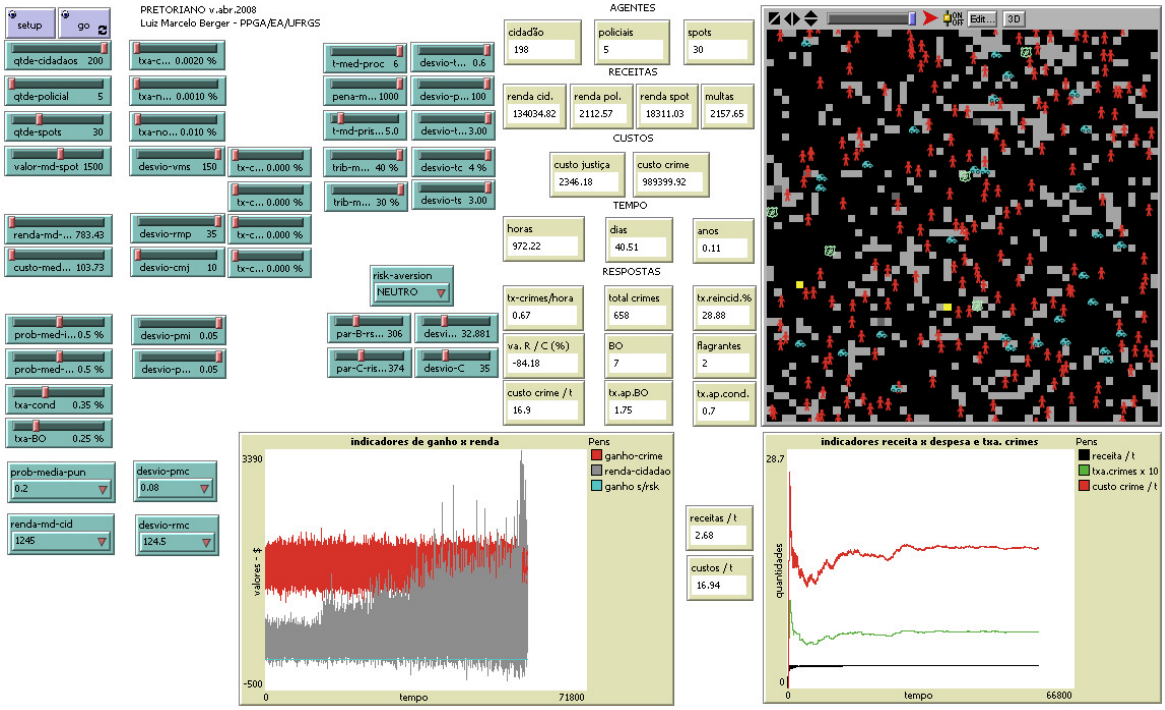


Figure 3
Simulator operating console

A brief description of the features shown in figure 3, includes on the left side sliders which control de microeconomic parameters the researcher is interested on modeling. On the center of the console are located the displays that show the variation of macroeconomic variables all along the simulation. Finally, there are three graphical facilities. In the bottom of the console is located the probability functions that are generated to simulate Becker's (1968) equation (1) and the output in terms of overall income and cost of crime of the artificial society, according to Shavell an Polinsky (2000) lessons. Finally, on the right side the interaction of the agents can be seen, along with the criminal events the researcher is willing to model, such as the geographical location of theft, police reports, criminal hot spots and eventually, the location where the perpetrator was caught up in the act by police enforcement agents. The interaction of the agents follow Cohen and Felson's (1979) and Clarke's (1995) studies. This dynamically generated interaction is random, depending only upon the input parameters used in the model.

[3] Brazilian currency is Real (R$). An approximate rate is 1 US$ = 2.25 R$ (2005).

Also, a desirable feature provided by the Netlogo 3.1.4 (Wilensky, 1999) platform is that the elapsed simulation time can be fully controlled, giving flexibility to the experiment in terms of evaluating agents' behavior and system macroeconomic outcome along time. Once the simulation starts, agents' interaction is random, being a function only of the microeconomic parameters given as an input data.

7. Conclusions

The purpose of the research was to create an agent-based model framework to make feasible the analysis of agents' behavior vis-à-vis the compliance of the criminal law in a computational framework. For that matter, the model has been developed to aggregate, simultaneously, microeconomic and macroeconomic variables. The former deals with specific agents behavior parameters suitable to the analysis of a given rule of law. In other words, it means that the parameters vary depending on the rule of law subject to research. This is important to the policymaker and legislators to see the implications, consequences and costs of different policies to deal with crime.

The simulation experiments intended two primary objectives. To verify the consistency of the model and, secondly, to validate the theoretical framework under which the model was based on. Both, the verification and validation tests were performed according to Law and Kelton's (1982) recommendations for modeling and simulation experiments.

The research has attempted to build a stable framework under which Becker's (1968) assessment over agents' behavior upon crime engagement could be applied. Along the simulation, macroeconomic variables reached stability regardless the overall cost of the market of offenses. Levels of agents' incentives, like average car value in monetary terms, individual's average income and average imprisonment terms for a given offense were kept in actual values.

The overall behavior of the artificial society is consistent with Becker's (1968) lessons and implications. Agents do respond to incentives prior any engagement in criminal activity, namely car theft, used in the performed experiments.

As such, the experiments showed that, increasing the amount of incentives to agents in terms of monetary standards, effectively prevent augmenting crime rates. Likewise, increasing the probability of detection and punishment p in equation **(1),** criminal activity figures decrease proportionally. Finally, the flexibility of the model allows performing different kinds of simulations, once the entry parameters can be defined and empirically obtained according to specific research interests, for example, for tackling *ceteris paribus* problems.

Agent-based modeling is potentially a very powerful tool for law and economics because:

(i) It increases the empirical understanding of how society works and help to exploit the emergence of regularities;

(ii) It increases the normative understanding, since the computing models can help design good norms and mechanisms for many kinds of criminal behavior

(iii) It increases the methodological tools since they give to researchers a new powerful method to study complex social systems when individuals are cooperative or non-cooperatives at the same time (Axelrod, 1997), and when norms and incentives dynamically change.

(iv) And finally, it can attain insights to researchers about methods and tools, concerning the functioning of complex systems and societies.

This kind of framework developed is still in its infancy, there is much more work to do, but the insight is very valuable to anyone interested in economics of crime and the implication of law and economics. In other words, an agent-based model applied to crime is important to study complex societies and their evolution.

References

Axelrod, R. ***The complexity of cooperation: agent-based models of competition and collaborations***. Princeton, Princeton University Press, 1997.

Axtell, R.; Epstein, J.M. ***Growing artificial societies***: Social Sciences from the Bottom Up, The MIT Press, 1996.

Becker, G. Crime and punishment: an economic approach; ***Journal of Political Economy***, n.2, v.76, 1968, pp. 169-217.

_____ .***Economic approach to human behavior***. Chicago University Press, 1976.

Carrera-Fernandez, J. e Pereira, R. Diagnóstico da criminalidade na Bahia: uma análise a partir da teoria econômica do crime. ***Revista Econômica do Nordeste***, 32: 792-806 novembro, 2001.

Clarke, R.V., Situational Crime Prevention, ***Crime and Justice***, Vol. 19, Building a Safer Society: Strategic Approaches to Crime Prevention, (1995), pp. 91-150.

Cohen, L.E., Felson, M. Social Change and Crime Rate Trends: A Routine Activity Approach; ***American Sociological Review*** 1979, Vol. 44 (August):588-608.

Cooter, R. Ulen, T. ***Law and Economics***. Addison Wesley Longman, 3rd Ed.1999.

Ehrlich, I., Crime, Punishment, and the Market for Offenses. ***The Journal of Economic Perspectives*****,** Vol. 10, No. 1. (Winter, 1996), pp. 43-67.

Fiorentini,G., Peltzman, S., ed.; The economics of organised crime; Centre for Economic Policy Research; Cambridge University Press, 1997.

Kingston, Paul W.; Hubbard, Ryan; Lapp, Brent; Schroeder, Paul; Wilson, Julia; Why Education Matters, ***Sociology of Education***, Vol. 76, No. 1. (Jan., 2003), pp. 53-70.

Law, A. M. & Kelton, W.D. ***Simulation Modeling and Analysis***. New York City, McGraw-Hill, 1982.

Mercuro, N. e Medema, S.G. ***Economics and the Law: From Posner to Post-Modernism***. Princeton, Princeton University Press, 1997.

Rao, A.S., Georgeff, M.P., Modeling Rational Agents within a BDI Architecture. **Proceedings of the 2nd International Conference on principles of Knowledge Representation and Reasoning** (KR '91), R. Fikes and E. Sandewall, eds. pp. 473--484. Morgan Kaufmann, Cambridge, MA, 1991.

Russel, S., Norvig, P., Artificial Intelligence: A Modern Approach, Prentice Hall Series in Artificial Intelligence. Second edition., 2003.

Scheinkman, J.A, Glaeser E.L; Sacerdote, B.; Crime and social interactions**.** ***The Quarterly Journal of Economics***, Vol. 111, No. 2. (May, 1996), pp. 507-548.

Schelling, T**.** ***Micromotives and macrobehavior***. New York: Norton, 1978, pp.137-155.

Shavell, S., ***Foundations of Economic Analysis of Law***. Harvard University Press, Cambridge, Massachussetts, 2004.

Shavell, S., Polinsky, A M.; The economic theory of public enforcement of Law; ***Journal of Economic Literature****;* Mar 2000; 38, 1; ABI/INFORM Global, pg. 45.

Simon, H. The architecture of complexity**.** ***Proceedings of the American Philosophical Society*****,** Vol. 106, No. 6. (Dec. 12, 1962), pp. 467-482.

Tullock, G. An economic approach to crime. ***Social Science Quarterly***, 50 (1): 59-71, June, 1969

_____ . Does Punishment Deter Crime? ***Public Interest***, summer, 1974.

Wilensky, U. ***Center for Connected Learning and Computer-Based Modeling***, Northwestern University, Evanston, IL, 1999. Available at: http://ccl.northwestern.edu/netlogo/. Access: dec. 15th, 2006.

Wooldridge, M.; **An Introduction to Multiagent Systems**. NJ, John Wiley & Sons, Ltd., 2002.