

Economic Analysis of Law Review

An Agent-Based Simulation of Car Theft: further evidence of the rational choice theory of crime

Uma Simulação de Furto de Carros Baseada em Agentes: evidências adicionais da teoria da escolha racional do crime

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RESUMO

Nos últimos anos o Brasil tem experimentado uma melhora de índices socioeconômicos e, simultaneamente, um problemático aumento da criminalidade urbana, seja contra a pessoa ou patrimônio, em especial com relação aos crimes de oportunidade. A aparente contradição desafia a comumente alegada correlação entre distribuição de riqueza e vários tipos de ofensa urbana. Aplicando-se o modelo baseado em agentes desenvolvido em Berger, Borenstein e Balbinotto Neto (2010), este artigo contribui para o debate por meio da avaliação da eficiência da polícia no combate ao crime de furto/roubo de veículos na cidade de Porto Alegre. Os resultados indicam que enquanto o policiamento ostensivo reduz a incidência do delito no curto prazo, seu efeito de longo prazo é inconclusivo.

Palavras-chave: Furto de Veículo; Escolha Racional; Simulação Computadorizada; Sistema de Multiagentes; Porto Alegre.

JEL: K42, C49.

ABSTRACT

In recent years Brazil has been experiencing an improvement in socioeconomic indexes and, simultaneously, a troubling increase in urban criminality, either against the person or property, particularly those related to the so-called crimes of opportunity. The apparent contradiction challenges common claims concerning the correlation between wealth distribution and various types of urban offences. Using the agent-based computational model of criminal behavior developed in Berger, Borenstein & Balbinotto Neto (2010), this paper contributes to the debate by assessing police efficiency towards car theft tackling in the city of Porto Alegre. Results reveal that although police presence inhibits criminal activity in the short run, the evidence is inconclusive in the long run.

Keywords: Car-Theft; Rational Choice; Computerized Simulation; Multiagent Systems; Porto Alegre.

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1. Introduction

Crime has been subject to intense quantitative research in recent decades, most particularly after Becker's (1968) seminal work on the economic approach of criminal behavior. However, criminological theories go as far back as the XVIII century with Beccaria's "*Dei Delitti e Delle Pene*" (On Crimes and Punishment) originally published in 1764, regarded as the first full-scale work to deal with criminal law system. In fact, Industrial Revolution was just taking place, bringing profound and enduring changes in European society, beginning at the United Kingdom and rapidly spreading to other western countries. The urban environment in Europe was experiencing a rapid and unprecedented economic growth and new challenges were just surfacing, bringing about enormous benefits for people, although paving the way to undesirable side effects such as an increase in criminal activity.

Literature regarding crime is vast, reaching a wide spectrum of society's interest. As society evolved to more complex structures, criminological research received extensive statistical analysis, which ultimately became a fundamental tool in criminological studies (Piquero & Weisburd, 2011; Barkan, 2009). The reason for the growing need of more precise and accurate tools can be found in the complexity and graveness of the phenomena all across countries holding different cultural levels, scenarios and backgrounds.

The social impact of criminality can be extensive³ and pervasive with deep economic roots as can be seen with criminal organizations crossing borders to seek unexplored markets⁴ within states ravaged from high rates of corruption⁵ reaching extremely hard and dramatic consequences, such as the recent war on drugs taking place in Mexico to violent clashes between enemy gangs and police in Rio de Janeiro *favelas*⁶, or even in recent violent riots that took place in London in 2011, which have been highly publicized in the media, highlighting the permanent seriousness of the issue.

To address the question, this article is divided into six sections. Section one deals with the main aspects motivating the work, with special attention to Brazil's historical background. In section two, selected modeling and simulation techniques are reviewed. Section three presents the theoretical framework of the model, inspired in Becker's (1968) work on crime and punishment and The Situational Crime Prevention Approach (SCP), which also analyses criminal activity through a 'rational agent' perspective. In section four, a brief description of the agent-based computational model architecture for criminal behavior detailed in Berger *et al.* (2010) is presented. In section five, a set of experiments derived of the model are presented applying a rational behavior approach to car theft, which can be considered as a crime of opportunity in order to discuss Becker's (1968) rationale of cost-benefit analysis and finally, in section six, we present the final remarks about what has been done in the precedent sections, conclusions, suggestions for further research and the limitations of the simulation experiments.

³There is a lack of sound Brazilian works, English-written, dealing with the issue. See Brand & Price (2000) for detailed analysis of the UK case.

⁴Barone & Masciandaro (2011) make insightful remarks into the relationship between money laundering and the legal economy, within the concept of the emergence of the "shadow economy".

⁵See Treisman (2000) for a cross-national study on corruption.

⁶*Favelas* is a widely known Portuguese term for slums.

1.1. Historical Background

Brazil's recent crime experience can be traced back to the 90's when a successful set of economic and monetary reforms, nicknamed *Plano Real* (Real Plan)⁷ switched the currency from a crippled and short-lived *Cruzeiro Real* to the current *Real*, providing the country economic and, most important, currency stability for sustainable growth.

Such economic initiatives have been successfully implemented, providing a long awaited forecast and planning capability. The economic reforms, which have been under way along this period were responsible for budget stability allowing long term planning for individuals and organizations. Overall, the effects have been widely positive in terms of fiscal and budget management.

As an immediate consequence, inflation rates dropped dramatically, coming from sky-high rates to ordinary standards known to most developed western economies, giving Brazilian currency the much needed stable and predictable exchange rate against other currencies and for putting money into families' pockets, allowing ordinary people to access market oriented values and prices for goods and services⁸.

Nevertheless, as a flipside to favorable economic conditions, public investment in law enforcement institutions did not keep the same pace, leading to underfunded and obsolete state police forces which along with an extremely bureaucratic and highly ineffective judiciary system regarding criminal procedure allowed a surge in criminal activity in urban areas, most particularly in the northeast part of the country, which has been ironically most benefited for public expenditures in order to fill an historic economic gap as compared to more developed regions, like São Paulo and Rio de Janeiro states.

This scenario brings about the discussion concerning the relationship between inequality, violence and the widely expected claim that an increase in living standards due to flow of investment would lead to better social conditions, and as a consequence, a significant drop in criminal records⁹. In fact, such claims are very controversial and numerous studies have been challenging hasty conclusions, particularly when cultural differences impact the results¹⁰. Indeed, the new economic situation in Brazil surfaced this debate: the economic upgrade experienced in more impoverished regions of the country brought along a boost in crimes either against property and persons as a side effect, against most optimistic expectations.

Data collected in major cities in the northeast region (Waiselfisz, 2012a, 2012b) pointed to a surge in drug market disputes the responsibility for much of criminal activity, since the economic boom drew the attention of potential crime lords to a new and unexplored market that

⁷ See Sachs & Zini Jr. (1996) for an in-depth study and Flynn (1996), for a political point of view. For a critical perspective, see Amann & Baer (2000). Averbug (2001) provides interesting insights regarding pros and cons of the plan in various dimensions, taking into account the period 1994-1999.

⁸ Critical analysis over social accomplishments as a follow up of *Plano Real* are mixed. Conditional cash transfer initiatives such as the Brazilian "Bolsa Familia" have both supporters and critics. It originally began under President Cardoso Administration in the nineties and was enlarged under President Lula. Those in favor state that reducing social inequality is worth taking some risks. An in-depth study can be found at Lindert, Linder, Hobbs & Briere (2007). Critics say the system must be temporary, in order to avoid political dependence and exploitation in the long run. In that regard, see Hall (2008).

⁹ See Fajnzylber, Lederman & Loayza (2002) for an in-depth investigation regarding the causality between income inequality and violent crime across countries.

¹⁰ See Neumayer (2005) for a discussion challenging the inequality-violence causality assumption.

could offer a highly lucrative perspective to offenders. Law enforcement officials were hardly prepared, particularly in more inner regions that could not keep up with well-organized, equipped and violent organizations that migrated to explore favorable market conditions with no competition¹¹.

Updated figures (Waiselfisz, 2012a, 2012b) show dramatic shift upward in respect to violent crimes, particularly those related to individuals fitting into the age range of 0-19. Overall, the murder rate within this population which was 3,1 per 100.000 in 1980 jumped to 13,8 per 100.000 in 2012, a 346,4% increase. From all reported murder victims in 1980, 11% were youngsters within that limit. Thirty years later, the amount jumped to 43%. Still, in 1980 only 0,7% of youngsters' deaths was caused by homicide as opposed to 11,5% of the deaths in 2010 in the same population.

The current scenario challenges studies that claim a causality relationship between better social conditions associated to a decrease in criminal activity (Sachsida, Mendonça, Loureiro & Gutierrez, 2010; Scorzafave & Soares, 2009) given the fact that economic boost in many impoverished regions in Brazil is historically unprecedented, particularly in the northeast part of the country.

On contrary, these regions have shown the highest rates in terms of crime committing increase (Waiselfisz, 2012a, 2012b) as compared to more developed and organized urban areas in Brazil, such as São Paulo, Rio de Janeiro and Belo Horizonte, three of the largest and most populated cities in Brazil, which have also been facing increasing figures related to crime, either against property or against the person, although in a lesser extent.

Such situation denotes a deep contrast between crime in major urban areas in Brazil as opposed to similar cities in America which are experiencing a more steady and constant decline in criminal behavior in recent decades, with the notable example of New York City (Zimring, 2007).

Urban criminality, indeed share some similarities regardless where it is actually taking place, that is, some specific patterns are able to describe particular forms of criminal engagement, which is the case of the so-called crimes of opportunity such as burglary, theft, robbery, possessing stolen property and, more generally speaking, those crimes against property (Cohen & Felson, 1979; Clarke, 1995; Felson & Clarke, 1998), which composes some of the most common criminal behavior related to urban environment¹². Similarities regarding such kind of criminal activity can be found in most urban situations that share similar characteristics (Felson & Clarke, 1998).

In this regard, a “market model”, along with a consistency with the ‘rational agent’ approach for offences (Ehrlich, 1996) fits the theoretical framework upon which the model is based on, since the relation between criminal activity and economics has already been well established (Cooter & Ulen, 2011; Posner, 2011; Garoupa, 2009; Shavell & Polinsky, 2000; Shavell, 2004).

In a market model perspective, advances in families' income might attract the interest of potential offenders, since the availability of suitable targets (Cohen & Felson, 1979; Clarke, 1980, 1995) may function as potential magnets for those engaged in such activity. Becker's

¹¹A new trend in terms of migration of criminal gangs to less protected “hot spots” located at less populated cities in Brazil has been extensively reported in the media, particularly some remote communities in the northeast of the country which have been ravaged by organized gangs engaged in bank assaulting.

¹²Strictly speaking, crimes of opportunity do not include offences against the person, such as assault or rape, for example. It mainly refers to property related crimes.

(1968) formalism on economic approach to criminal behavior opened a new path for researchers and played a fundamental role formally bringing the *rational agent* into the realms of criminological studies.

Urban violence, therefore, has become a major focus of concern in terms of public policy towards criminal law enforcement policies, particularly in similar densely populated areas not only in Latin America, but also in major cities in Africa and Asia and to a much lesser extent in North America and Europe.

2. Modeling and Simulating Crime

Crime modeling has the explicit endeavor of using hard sciences methodologies to understand the patterns of criminal behavior. In fact, scholars have been addressing the issue in various directions. Blumstein (2002) applies an Operations Research approach to model criminal career and the Criminal Justice System. Auerhahn (2008), noticing the complex and non-linear characteristic inherent to social systems, proposes dynamic systems as a promising alternative as an analytical technique, claiming that if there is such thing as a constant in criminal justice that should be the “the reality of change”.

Barone & Masciandaro (2010) use a dynamic model to simulate the relationships within the context of organized crime, money laundering and legal investments. Frank, Dabbaghian, Reid, Singh, Cinnamon, & Brantingham (2010) design mathematical structures to spatial distribution of crimes, using offenders’ home locations and the locations of their crimes to define directional and distance parameters. More recently, agent-based systems has been emerging as a methodological tool to simulate various types of criminal activity (Makowsky, 2006; Pavon, Arroyo, Hassan & Sansores, 2007; Groff, 2007, 2008; Wilhite & Allen, 2008; Rahut & Junker, 2009; Malleon, Heppenstall & See, 2010; Pitcher & Johnson, 2011) as a modeling and simulation technique to simulate criminal behavior.

The growing complexity and non-linearity (Auerhahn, 2008) of the interrelations among the various elements of our society are among the main reasons behind the interest in Agent-based systems as a means to create artificial societies (Axtell & Epstein, 1996). Also, field experiments and data collecting when crime is concerned is costly to obtain, opening the way to computer simulation as a reliable means for research.

Additionally, criminal modeling and simulation is deeply concerned in achieving meaningful and credible results, which ultimately amounts for: 1) Describing the behavior of systems; 2) Constructing theories or hypotheses that account for the observed behavior; 3) Using these theories to predict future behavior, that is, the effects that will be produced by changes in the system or in its method of operation (Shannon, 1975).

In a complex system 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, the outcome due to individuals’ interaction might not show clear cause-effect patterns among micro variables unlike their macro consequences as Scheling (1978) showed in a simple and intuitive way when studying segregation patterns.

An agent-based computational approach poses a departure from usual social research methods since it attempts to address crime committing by using an artificially conceived environment to perform experiments to study alternatives concerning criminal behavior tackling, following an emerging research area also known as artificial crime analysis (Liu & Eck, 2008) or

computational criminology, which offers an interesting cost-benefit ratio vis-à-vis more traditional methods of analysis, in particular, when different scenarios are subject to evaluation under a large number of complex and interdependent variables.

The availability of a metamodel as a surrogate to the original complex simulation model is particularly useful when applying the original model is a resource-intensive process (e.g. in terms of model preparation, computation and output analysis), as it is typically the case in complex simulation models, such as probabilistic analysis (Fang, Runze & Sudjianto, 2006). Also, a cost-benefit analysis demonstrates that computer simulated techniques offer “the advantage of being able to visualize and understand the effects of (often expensive) program and policy changes prior to implementation” (Auerhahn, 2008, p. 294).

The major concern when approaching crime phenomena is establishing solid cause/effect relations. Gottfredson & Hirschi (1990, p. 3) mention that “criminologists often complain that they do not control their own dependent variable”, which is a major shortcoming in terms of quantitative accuracy. The cause/effect relationship in terms of criminal behavior, therefore, is not an intuitive assessment and can only be addressed when carefully placed in context (Zimring, 2007, 2008) which did not prevent criminality from being subject to permanent and extensive research by numerous scholars from a wide diversity of specialties. Few topics seem more important than the basis of social and political order, more interesting than the question of human nature, or more practical than the understanding of violence (Gottfredson & Hirschi, 1990).

3. Modeling Criminal Behavior: the economic analysis of crime and the situational crime prevention approach

Applying the economic analysis of criminal behavior towards the law is first and foremost an *analytical method* for creating a model suitable to translate individuals’ behavior from a micro level to a macro level of analysis (Becker, 1993). Criminology, in this sense, has been benefiting from a wide array of contributions coming from disciplines ranging from biology to sociology, with very different perspectives. An economic approach, however, has the ability to provide a methodological solid ground upon which a framework of analysis can be designed, especially in terms of building a computer based system able to mimic individuals’ behavior toward the enforcement of criminal law in terms of utility functions and preferences.

Assuming rationality applied to crime, only means that people act on purpose in the search of objectives autonomously chosen, that people prefer more to less of the things they desire, regardless the legal nature of the conduct (licit or not). It is mainly a description of human behavior, and as a way of identifying the foreseeable reaction of an individual when confronted to such situation.

There is no doubt that criminal decision making is a highly complex and dynamic endeavor with numerous constraints involved, each one assigned to a particular agent within a specific scenario, that might as well change over time. As Becker (1993, p. 386) asserts “actions are constrained by income, time, imperfect memory and calculating capacities, and other limited resources, and also by the opportunities available in the economy and elsewhere”.

Such remarks also deal with concerns with oversimplification when dealing with the multiple criminological scenarios that arise in actual situations. Studying crime often involves behavioral extremes, when human nature meets its worst: greedy, intemperate, vicious and vio-

lence (Zimring, 2008). All these characteristics, abundantly found within criminal behavior context must be carefully addressed through empirically validated data.

An economic approach to criminal behavior, therefore, shall be able to deal, *methodologically*, with all these constraints providing the means for understanding social phenomena, with solid and sound methods for analyzing the effects of the implicit prices that laws attach to behavior (Cooter & Ulen, 2011), which means its translation in terms of utility functions and preferences.

Accordingly, the model seeks to establish the dynamic relationship between micro and macroeconomic variables, in the context of the enforcement of criminal law. This feature makes the model turn away from a pure statistical analysis which is always a snapshot taken in a very specific context and timetable, that is to say, a *static* analysis. 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 agent-based model (Berger *et al.*, 2010), uses Becker's (1968) formulae as the basic strategy used by agents when engaging (or not) in criminal activity within a given context which states formally: $g > p(f + \lambda t)$ (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.

The bridge that allows matching Becker's (1968) abstract analysis of crime with real world situation is made through the Situational Crime Prevention (SCP) theory, which works within the realms of the cost-benefit analysis. Instead of looking into subjective assumptions concerned with fundamental roots behind the impulse to offend, it concentrates efforts to solve, or at least alleviate, immediate problems faced by most citizens living in large and, sometimes, chaotic urban areas, which is the case of most Brazilian megalopolis^{13,14}.

As a rational approach, SCP makes a shift in its methodological tools as opposed to other criminological approaches. Its settings are focused into discrete managerial and environmental changes intended to reduce the opportunities or incentives for crime, rather than looking into subjective conditions of offenders (Clarke, 2009). In this regard it's consistent with Becker's (1968) instrumental rationality as a tool in the economic analysis of crime. Routine Activity Theory (Cohen & Felson, 1979) also follows the same reasoning, since it requires the availability of suitable targets to potential offenders, which means in both cases a cost-benefit analysis by the agent prior to engaging in the conduct.

What makes SCP distinctive in respect to other criminological theories is a pragmatic perception about criminal activity. In fact, it doesn't suppress the need to understand the causes of crime which can definitely be of utmost importance in terms of long run public policies for crime fighting. However, urban criminality happens in a daily basis frequency, particularly in large and densely populated cities of the world. The question that has been raised¹⁵ through SCP

¹³Extensive metropolitan areas or long chain of continuous urban areas can be found not only in Third-World Countries but also in most developed Countries as well, sharing in some cases similar situations regarding criminal activity, which could be seen in France's nationwide urban unrest in 2005 and in London in 2011.

¹⁴As for 2010, São Paulo is home of 11,2 million people, Rio de Janeiro, 6,3 million, Belo Horizonte, 2,3 million (IBGE, 2010).

¹⁵ Clarke (1980) makes interesting assessments in terms of timing related to crime fighting alternatives, particularly relating the public perception of offences and the way authorities respond to it.

approach deals with practical and immediate actions that must be taken in order to face an ongoing situation, without disregarding other suitable actions dealing with causes of offences.

4. An Agent-Based Architecture for Criminal Behavior

The computational architecture (Berger *et al.*, 2010) translates legal concepts into agent-based entities, making criminal law concepts suitable to perform simulations within an artificially controlled environment. Criminal Law¹⁶ deals essentially with those actions intended to do a great amount of harm, although the extent and degree of such damage is not the same, considering for example burglary as compared to murder or rape. The distinction that criminal behavior has in respect to other branches of law is that society finds some conducts morally unacceptable giving the state the duty to enforce its commands, regardless the interest of the parties in most vicious acts. It is the body of legally enforced rules related to crime. In most countries, such rules exist specifically to deal with those conducts that threaten, harm or endanger people, particularly involving safety, welfare and privacy situations.

Criminal Statutes, along with a detailed description of the specific conducts leading to harmful outcomes, also sets out the sanctions or punishments to people that do not comply. Historically, Criminal Law evolved to be enforced and imposed only by the State, which means public enforcement as opposed to private enforcement, extensively found in Civil Law, where the focus is mainly in dispute resolution between parties rather than punishment. Thereby, every criminal rule requires an *actus reus*¹⁷, or the Latin for guilty act, manifested by an agent towards another.

Also, a *mens rea*¹⁸ must be present, which is the Latin for “guilty mind”, that reveals the intention by the agent to commit a legally wrongful act. For the sake of this work it is assumed that agents always ‘commit the *actus reus* with *mens rea*’, so that the consistency with the economic approach of crime is warranted. Finally, any criminal rule can only be enforced within the limits of a Jurisdiction^{19,20}.

Assignment of a Jurisdiction can be made not only by means of physical boundaries, but also by legal interest, which is the case, for example of some felonies that are prosecuted in federal courts as opposed to others which face State Jurisdiction. The interest in keeping these concepts as the basic ground to all simulations goes to verification, validation and replicability purposes, since such definitions can be found in almost every criminal statute of the world.

Accordingly, the model has been built upon a set of three agents that dynamically and randomly interact with each other and with the environment, simulating, as close as possible, real

¹⁶ For an introductory and comprehensive analysis concerning the fundamental concepts of Criminal Law see Dressler (2007), Kadish, Schulhofer & Steiker, (2007) and Kaplan, Weisberg & Binder (2012) for further reading. Also, as a primer to criminological theories, Siegel (2010) covers most topics dealing with probable causes of criminal behavior.

¹⁷ Law Latin “guilty act”. The wrongful deed that comprises the physical components of a crime and that generally must be coupled with *mens rea* to establish criminal liability’ (Garner, 2009, p.41).

¹⁸ Law Latin “guilty mind”. ‘The state of mind that the prosecution, to secure a conviction, must prove that a defendant had when committing a crime, criminal intent or recklessness’ (Garner, 2009, p.1075).

¹⁹ Brazil’s penal system share this similarity with America, although not providing Federal States full legislative autonomy in terms criminal statutes, as it is the case in USA.

²⁰ Jurisdiction: ‘A Government’s general power to exercise authority over all persons and things within its territory’ (Garner, 2009, p. 927)

criminal events, showing how the agent-based model has been designed to represent the functioning of the criminal law translating legal crime vocabulary into a systems model. It reproduces the fundamental topics behind criminal law enforcement dynamics (Berger, *et al.*, 2010).

5. Computational Implementation and Experiments

5.1. Experiment Description

The algorithm (2) has been designed as a proxy to Becker's reasoning (1). The variables within the programming code assume normally distributed random values. The application dashboard allows handling both mean and standard deviation of input variables available, adapting the figures to specific scenarios (Berger *et al.*, 2010).

The selection of the disutility factors are related to Brazilian criminal experience in recent years in terms of the effectiveness of public officials when dealing with crime fighting²¹. As described in section 1, figures are not encouraging, making such variables very sensitive to assess in a simulation process. Ultimately, the simulation serves as a test of the overall efficiency of Brazilian Public Enforcement of Criminal Law.

Indeed, Brazilian Criminal System, especially Police forces, suffer from poor performance in terms of gathering credible reporting of crimes from victims²², due to a deeply rooted public perception of the ineffectiveness of both police and judicial work, leading to a high degree of impunity.

It's been well established empirically that actual perception of risk of punishment is a determinant deterrence factor regarding the decision making in terms of engaging or not in criminal activity (Cooter & Ulen, 2011). It shows that agent's must have a deep sense that there is a high risk of being caught and the algorithm has been designed so that the probability of punishment is a function of the deterrence effect of public policies towards a given criminal activity.

The pseudo code (2) displays the agent's decision making process, taking into account Brazilian sensitive criminal issues as disutility factors, which are programmed in the NetLogo (Wilensky, 1999) application, which assumes that the perception of punishment that affects probable profit by a perpetrator is heavily dependent on the effectiveness of public policies (DF_n – Disutility Factors) towards the enforcement of criminal law. This dependence establishes the relationship between the effectiveness of due process and police work with the primary aim of criminal law, which is to rid society from those morally unacceptable behaviors.

²¹Criminal Law has five primary objectives commonly referred in the doctrine: retribution; criminals ought to suffer in some way, in order to “balance the scales”. Deterrence; fundamentally to discourage an offender from engaging in criminal activity. Incapacitation; designed to put away criminals from society, mainly by means of jail time. Rehabilitation; with the goal of recuperating an offender as an active member of society and Restitution; which is a civil law institute aiming to repay a certain amount unlawfully obtained in order to get the victim back to his original situation.

²²With the notable exception of offences against the person, like rape, homicide or assault which have a high rate of reportability, since most victims check in a hospital for first care and doctors have to report when traces of such crimes are spotted.

Do

Set gain

```
set  $U_T = p * [ \text{fine} + [ (DF_1 + DF_2) * (DF_3 + DF_4) * [ U_n * DF_5] * [ 1 / DF_6 ] ] ]$       (2)
  if gain > agent's income
  crime
end
```

Where:

gain - utility function (*opportunity agent*) obtained from crime, collected in the “market”. It's a monetary value expression of the expected utility obtained with crime.

U_T - overall adjusted *licit* utility available to the *citizen agent*.

U_N - is a monetary expression of the net utility available to the agent without resorting to criminal means.

p = probability of punishment / getting caught perceived by the agent-effectiveness percentage.

fine = monetary sanction imposed to offender.

DF_1 = effectiveness rate of police investigation in indicting suspects of crime.

DF_2 = effectiveness rate of credible reporting of crimes to the police

DF_3 =conviction rate for a single crime.

DF_4 = effective rate of conviction due to simulation process

DF_5 = average imprisonment time assigned to a convicted criminal²³.

DF_6 = time of duration of criminal due process²⁴.

DF_2 and DF_4 function as “learning” factors to agent's during the execution of the simulation. Depending on the performance of the simulation, those variables collect the data coming from the interactions and adjust the others, increasing or decreasing the overall results, since agents are “supposed to learn” from the consequences of their acts.

The input data reflects normalized car theft figures in the metropolitan area of the city of Porto Alegre, Brazil's southernmost capital, which means that for every different crime experiment a new set of input data must be gathered. Adjusting DF_n to each different scenario assures that enacting any given statute will only be effective as long as a foreseeable outcome takes place as expected. Otherwise, the provision has no practical effect. Ultimately, it means that causes which lead to any crime are different, although similar in some aspects.

The primary aim has been to create an operational framework which could be easily customized for each particular scenario. This mindset, however ingenious, had the clear intention to allow the applicability of the model after few adjustments to a wide range of criminal situations. It attempts to provide replicability (Liu & Eck, 2008) as a key feature, since one of the major

²³On average, jail time in Brazil is extremely short as opposed, for example, to American standards for similar criminal conducts, being in some cases almost as non-existent.

²⁴One of the most problematic issues faced in Brazilian criminal system is the reasonable duration of judicial criminal procedures. One of the main causes of impunity in Brazil rely on criminal procedures and trials which can last for decades, especially person-based offences, which depend heavily on evidence gathering, forensics and testimonies that can be cross-examined and challenged all the way up to the appellate courts, leading to an extremely high rate of incidence of statute of limitation, which in the end has the same effect as a mistrial or even as an acquittal for offenders.

concerns inflicting criminology altogether is its difficulty to perform highly controlled experiments and to measure causal factors accurately. Any simulation process will reflect such constraints balancing from more or less detail in order to make its approximation of reality.

Brazilian Criminal System ineffectiveness, from police work to judicial procedures, generally leads to high rates of impunity. Keeping that perspective, experiments were performed in order to assess different levels of efficiency in terms of police and judicial work (public policies) which can be implemented more rapidly. In this regard, the selection of the disutility factors (2) were consistent with the rational choice approach and the findings of Cohen & Felson (1979) and Clarke (1995), when describing the Situation Crime Prevention (SCP) approach. Social considerations, such as wages, family assistance and education were not considered as variables in the experiments.

Car theft is a highly lucrative “market of offences” in Brazil, mainly due to a black market of spare parts which can be found almost anywhere across the country. The “market” is constantly flooded with gear illegally obtained, keeping the whole “industry” in motion. Brazilian Law requires from dealers inventory of all items, with clear registration of origin for all products on sale. However, law enforcement forces fall short when it comes to personnel available to act on the frontline. Moreover, bribery and corruption among law officials is very common and deeply rooted, due to a highly lucrative and low risk activity. Also, the auto-makers, instead of bringing prices down to make less interesting to buyers the spurious equipment, keep it extremely out of reach. Turns out, potential buyers find extremely attractive the bogus parts offered in the “market of offences”, which can cost four to five times less than original ones and since the law enforcement is very poorly accomplished, the cost-benefit analysis attracts buyers, boosting the “industry” for more illegal items.

5.2. Discussion

Experiments were performed²⁵ to confront major issues currently under scrutiny in Brazilian Criminal Legal System regarding car theft in the metropolitan area of the city of Porto Alegre, Brazil. As mentioned in section 1, the widespread perception of impunity is heavily supported by actual figures²⁶. Crime fighting in Brazil suffers from a wide array of difficulties, which can be found not only in obsolete statutes regarding due process procedure, but also within police investigation and deterrence policies. Table 1 displays the experiments findings focused on the analysis of major disutility factors affecting Brazilian criminal system. Income figures are shown in Real (R\$), for simplicity purposes²⁷.

²⁵The experiment design follows Law (2007) steps for a simulation study, pp.66-70.

²⁶In recent years The Brazilian *Conselho Nacional de Justiça – CNJ* (National Justice Council) which is responsible for overlooking and addressing administrative issues concerning Brazilian Judiciary has been annually releasing statistical data dealing with sensitive aspects of legal system inefficiency. All data is freely available at www.cnj.jus.br (in Portuguese).

²⁷ Brazilian currency is Real (R\$). An approximate rate is 1 US\$ = 2.25 R\$ (2005).

Table 1 - Simulation experiments results

	Parameters	A	B	C	D	E	F	G
1	Population	400	400	400	400	400	400	400
2	Vehicles	60	60	60	60	60	60	60
3	Average vehicles utility (R\$) ²⁸	2500	2500	2500	2500	2500	2500	2500
4	Average utility available for offenders	2000	2000	2000	2000	2000	2000	2000
5	Probability of detection (%)	10	<u>80</u>	10	10	10	10	10
6	Police agents available on site	1	<u>200</u>	1	1	1	1	1
7	Probability of arraignment ²⁹ (%)	10	10	<u>95</u>	10	10	10	10
8	Average fine (R\$)	3900	3900	3900	<u>20000</u>	3900	3900	3900
9	Average Jail time actually served (years) ³⁰	0,5	0,5	0,5	0,5	<u>15</u>	0,5	0,5
10	Due process length (years)	6	6	6	6	6	<u>0,5</u>	6
11	Probability of Conviction (%)	40	40	40	40	40	40	<u>95</u>
	Results							
12	Crime Rates / per hour	2,98	0,70	2,96	2,20	2,79	2,80	2,90

Rows 1 to 4 show input parameters that were kept steady all along the simulation experiments. They reflect average figures as compared to real situation in the selected location. Column A serves as the original template for comparison reflecting normalized actual data gathered. Each one of Columns B to G varies the disutility factors, *ceteris paribus*, used in the experiment as compared to the original figures.

Row five, in particular, reveals the average police efficiency in solving crimes, which rarely goes beyond 10% of reported events. In some cases, such as homicide, solvability rates can actually drop to less than 5%³¹.

Updated information obtained at official databases³² reveals that Police / Inhabitant ratio is 1/400. Similarly, vehicle /inhabitant ratio is 1/6. Average net profit by criminals amounts to R\$ 2.500,00³³ for each singular event, given the fact the vast majority of stolen vehicles supply a highly lucrative black market of spare parts all across the country. Most offenders who were caught by law enforcement agents reported not having high legal incomes, making them very

²⁸Average amount of money an offender receives for each “successful abduction” in Brazilian currency Real.

²⁹The arraignment takes place when police investigation finds enough evidence to charge a suspect of a crime. In some American States it’s also called “initial hearing”. In Brazilian criminal system, however, the probability of some selected crimes ever be reported to police, much less be investigated, drop to striking 5%.

³⁰Brazilian criminal procedure states that all prisoners serving jail time are entitled to so called “regime progression”, regardless what crime has been committed, which technically means that after some time served behind bars, an offender can be legally released, although still serving the terms of the sentence. An average jail time for car theft /robbery actually served by offenders hardly reach a year long, after that the offender can legally obtain parole.

³¹See www.cnj.jus.br for further information (In Portuguese).

³²See www.ssp.rs.gov.br (In Portuguese).

³³Such figures are difficult to be obtained in accurate ways. An estimate sample has been taken from reports available on major Brazilian newspapers such as *Folha de São Paulo*, *O Estado de São Paulo* and *Zero Hora* (in Portuguese).

prone to committing crimes, when approached and commissioned by criminal organizations. Figures shown on row 4 follow such rationale and were also obtained by random sampling newspapers reports.

Police efficiency in terms of deterrence and investigating crimes can be assessed in row 6 which shows very accurate figures³⁴ concerning the probability of law enforcement agents solve crimes and return stolen property to rightful owners.

Rows 7 to 10 deal specifically with judicial efficiency in prosecuting and preventing the escalation of such behavior. All shown data was obtained from sentencing decisions held by state court with jurisdiction over the cases³⁵.

Simulation experiments are presented in columns A to G. Simulations have faced 15 rounds, taking 10 min. each, on average, to reach steady point. Numbers in *bold / italic* show the variation on disutility factors, *ceteris paribus* aiming at assessing most efficient policies in order to prevent crimes.³⁶

Overall, results (row #12) reveal that judicial efficiency improvement alone do not, at first glance, contribute to much lower rates of criminal activity, although having some significance.

On the other hand, when probability of detection nears 80% - when almost 1/3 of the agent's population is comprised by law enforcement agents (column B) - risk neutral agents interested on easy targets rather prefer taking chances somewhere else. It doesn't mean, however, that criminal intentions have been eradicated, just as Clarke (1980, 1995, 2009) extensively points out. It simply shows that a typical crime of opportunity can be effectively deterred by adjusting measures to make clear to offenders that they are actually very likely to get caught.

It's not the case, however, of supporting an unrealistic decision to deploy police enforcement agents on such proportion, vis-à-vis its prohibitive cost. But it surely demonstrates Becker's (1968) rationale that deterrence is heavily based on actual probability of offenders "getting in trouble" so that effectively disincentives undesired behavior. Communicating an increase in cost of crime leads to changes in the risk perception and learning curve of potential offenders thus improving deterrence, crime reportability and prosecution effectiveness (arraignment leading to indictment).

A question might arise when comparing the deterrence effect of a larger force at plain sight: Having almost 1/3 of the whole population comprised by law enforcement agents shouldn't be expected to see greater reduction on crime rates (12, B)? In fact, other disutility factors also play an important role in the discussion, such as offenders who actually already have a criminal career and will not easily give it up³⁷. Also, jail time effectively served in Brazil for such crimes rarely reach more than five years. Brazilian criminal law states that convicted offenders are allowed to convert jail time into alternative sanctions, such as fines or probation³⁸. It's not unlikely to expect that risk - prone agent's would be attracted to such incentive, given the highly profitable market at his disposal, with minimum loss probability.

³⁴ See www.cnj.jus.br (in Portuguese) for updated numbers.

³⁵ See www.tjrs.jus.br (in Portuguese) for free access of state judges rulings.

³⁶ Notice that experiments took into account a very specific criminal event: car theft/robbery. It doesn't correlates to any other crime, other than those considered crimes of opportunity within very careful considerations

³⁷ They should not be considered risk neutral in terms of modeling.

³⁸ In Brazil, every convicted offender sentenced to serve an imprisonment term lower than eight years is automatically entitled to such benefit, regardless the crime committed.

Finally, judiciary efficiency, which deals with due process length, fines imposed, conviction rate, jail time length, takes much more time to be assimilated, assuming all previous steps were successfully accomplished, such as an offender who is actually indicted and convicted and is currently serving an imprisonment term behind bars.

6. Conclusions

Urban violence in Brazil is a highly complex social situation which cannot be explained solely by poor wealth distribution, particularly in terms of crimes of opportunity. In fact, simulation experiments related to car theft showed that police and judiciary efficiency plays a fundamental role when perception of impunity is concerned. Public expenditures towards reducing incentives to engage in criminal activity have shown little – if none – progress in recent years.

Although a number of criminological theories (Siegel, 2010) have been put forward trying to serve as an umbrella to explain deviant behavior, empirical research in the last decades indicates that motivation for crime still puzzles scholars. It is possible, however, to establish correlations among certain types of crime, such is the case of crimes of opportunity, which ultimately led to the development of Situational Crime Prevention Approach as an effective and suitable model of analysis, although limited in many respects.

The experiments performed to address current Brazilian situation through a rational approach of criminal behavior, as exposed mainly by Clarke (1980, 1995, 2009) and as a “market of offences” (Ehrlich, 1996), showed consistency with the theoretical framework, where the availability of suitable and unprotected targets (Cohen & Felson, 1979) function as attractors to criminals. It also reveals the concrete effect of ill prepared police forces to prevent crimes, which combined with costly, lengthy and inefficient judiciary procedures increase the public perception of impunity.

The experiment also showed that probability of detection has a higher impact on likely offenders, although not completely eliminating the threat³⁹, as should be expected. Indeed, a steady, long and profitable criminal career plays an important role in results, along with a highly lucrative black market that still stands out untouched. Also, it highlights the systemic approach of crime fighting, since isolated actions are unlikely to yield noticeable results in the long run. In fact, on the contrary, a pure military occupation would just transfer criminals to less protected neighborhoods, just as recent Brazilian experience in Rio de Janeiro has showed⁴⁰.

A distinctive observation coming from output findings displayed in table 1 show that public expenditures must be accompanied with thorough considerations concerning the urgency where else to allocate scarce available resources, since the impact on public perception can vary depending upon how long such investments take to show observable results. Changes in legislation and criminal procedures in Brazil usually take years of deliberation before being legally effective. Brazilian judicial system have long insisted with obsolete and ineffective criminal procedures which in most cases end up falling into statute of limitation situations, preventing any kind of

³⁹Becker (1968) formally addresses the question stating the impossibility of eradicating crime beneath some point where it would be too costly.

⁴⁰This effect took place in 2011 when Brazilian police forces stormed a number of *favelas* in Rio de Janeiro to expel drug lords and to disrupt criminal organizations’ structure. Barely a year later, most criminals headed back to reclaim their territories. International media reported extensively from Brazil, in light of its consequences on upcoming events such as the World Soccer Cup in 2014 and The Olympic Games, in 2016.

punishment to criminals, even those already convicted awaiting sentencing. Such bizarre scenario is one of the most recurrent in Brazil's criminal experience.

As showed in table 1, the Situational Crime Prevention approach demonstrates that in the lack of any other prospect of rapid increase of judicial efficiency, the best case scenario would be allocating resources to improve police forces availability in order to make it more risky to offenders to engage in criminal activities, which deliver positive results in the short run. However, simulation experiments are inconclusive in respect to long run consequences, since a number of important variables are left out such as the relationship between a steady and highly lucrative "illegal market", career criminals and migration models.

Increasing probability of detection suggests questions that could be addressed in further research: given the specificity of the Brazilian situation, what amount of investment to improve judiciary efficiency would be necessary to impact prevention of crimes of opportunity, assuming a previous thorough cost-benefit analysis? Considering that crime figures, not only concerning car theft, can vary across the country, further experiments could be performed testing the rational choice approach in other major urban areas, collecting specific input data to validate the hypothesis. Since Brazil has a continental extent, what role plays migration of criminals to less protected sites in the long run? How important a criminal career can be and in what level of incentives the law can effectively contribute to reduce profitability of black market? Such questions are still unanswered.

7. References

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