Dissecting Crime through ABM. From Theory Testing to Policy Design

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Abstract

This paper aims at presenting the potential intersections between Agent-based Modeling and crime research also focusing on criminal policy making issues. Simulated experiments via ABM have the potential to be a powerful tool for exploring criminological theory as they could be useful to advance, test or refine theories. Agent-based simulations allow a generative explanation of crime which aims at understanding how crime patterns develop (the mechanisms that give rise to crime patterns or that prevent crime from clustering). From a methodological point of view, there are many reasons why it is appropriate to investigate the relationship between ABS and crime analysis. The use of agent-based computational method would be considered particularly beneficial in cases where empirical research is limited by the inability to conduct field trials. One of the main challenges of crime simulations is to investigate the spatio-temporal dynamics of crime [20]. As regards criminal policy research, it was suggested how this technique could be useful to anticipate consequences accruing from one type of intervention over another and to provide a sort of pre-test of certain crime prevention programs, able to suggest any changes before their empirical test. The current debate in the field regards predominantly the transparency with which researchers describe the rationale for the choices they make during model design and implementation [10]. The incorporation of empirical knowledge to assess the parameterizing and calibration of the models is needed in order to inform both theory and practice.

Keywords

Agent-Based Models, Crime research, Criminal policy.

1. Introduction

Criminological theories have developed through alternative explanations of why people come to engage in criminal behavior. On the one hand most criminologists look at the micro level variables to explain individual behavior, related for example to individual attitudes or propensities, psychological traits referred as criminality, low self-control [8], or also the variables of the individual rational choice [2] as well as the immediate micro level social environment of the individuals to explain their behavior, through the main argument that criminal and /or deviant behavior is learned in interaction with others. On the other hand, some theorists look to macro level dimensions to explain criminality and crime patterns (social, economic and also political factors) for example the classic strain or anomy theory of Robert Merton which refers to the social structure in which individuals are embedded to explain criminal outcomes.

Explaining criminal behavior necessarily requires an examination of individual related variables, as the individual decision making, within the context of social processes that occur over time, which are multifaceted and include spatial, temporal, and cultural dimensions. Collecting data on and modeling these processes is difficult using traditional empirical approaches.

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To address these challenges Epstein and colleagues [4; 5] suggest a generative approach, which usefully applies to crime explanations, which examines how macroscopic regularities (e.g. crime patterns in space and time) develop from the actions and interactions of individuals. The primary instrument of such an approach is a computational laboratory in which the researcher creates an artificial society, that is the virtual laboratory of a simulation. The individuals, called agents, in the artificial society behave according to the assumptions of the criminological theory. The agents in the model represent real world entities such as people, organizations, and groups. They interact with other agents and with the environment itself. The decisions made by one agent, in turn, influence those of others. Agents' actions may also influence the decisions of others directly because of their presence or the actions they take, or indirectly by affecting the environment within which they act.

The researcher observes whether the outcomes in the artificial society match what the theory would predict as well as empirical criminal trends.

So, agent-based modeling (ABM) is one type of generative approach and it allows to implement the so called Coleman's casual macro-micro-macro "transitions" and their reciprocal influences. That is, how the environment affects or constrains individual choices and behaviors and how the individual-level criminal action might translate into observable macrolevel crime patterns. We also refer to the bottom-up approach on which agent-based simulation relies which means that starting from a few, simple, theory-based rules that inform the behavior of individual agents (and their interactions), the model generates macro-level crime patterns (they often acquire the property of emergence which refers to unexpected consequences) [4; 7].

2. ABM and Criminological Theory

By contrasting empirical and computational experimentation within criminology, Eck and Liu [3] state that simulated experiments provide a bridge between theoretical explanations and empirically inferred representations of crime patterns. Agent-based simulations help criminologists to face the weakness of theoretical explanations of crime mainly written in common languages and often subjected to multiple interpretations. There are different ways in which ABM could support improvements in criminological theorizing.

Firstly, ABM can be useful to facilitating the formalization of a criminological theory, because the transposition of a theoretical assumption into a computational model, forces the researcher to specify a theory without ambiguity, increasing the possibility of making concepts measurable and developing its internal coherence. Simulations provide a rigorous formalization of a certain theory for empirical testing and experimentation [7]. Indeed, simulation requires that the theory's assumptions must be operationalized as a computer algorithm that is consistent with the theory. The result is a more formalized theory [1; 12]. In other words, agent-based simulation requires the researcher to specify the causal mechanisms [12] by which a hypothesized independent variable gives rise to the dependent variable, according to the theory incorporated into the simulation model. The process of decomposing theories into computational formalisms "such as the rules that govern agent behavior, is useful in that it provides researchers greater insight and demands that they specify theories and concepts in explicit terms. This can highlight potential inconsistencies or shortcomings and, by doing so, contributes to the subsequent strengthening of theory [18].

Secondly, ABM help to test and refine specific theories of deviance, because the researchers observe whether the model (and then the theory on its basis) is sufficient to generate an outcome that looks like the empirical distribution of the dependent variable observed. If the simulation outcomes do not match the empirical data, the theory is falsified. Otherwise, it suggests that the theories encapsulated into the software may be sufficient to explain the phenomena [12].

Lastly, the possibility to advance a theory is enhanced by applications of crime models because to the extent modelers carefully document their choices they make and the details of how they represent a construct, the transparency of the model design and implementation is increased [10]. Subsequent modelers can then build on that foundation and make systematic, incremental changes to it, as necessary. Explicit descriptions of the reasoning behind modeling decisions would also contribute to provide progress toward formalization of theories in criminology [18]. In this way, the explicit

operationalization of constructs can help build cumulative scientific knowledge and advance theories [10].

3. ABM and Criminological Research

The principal argument in criminology is the need for complementarities between the experimental or quasi-experimental approach and the simulation one in order to conduct crime experiments [10]. The use of agent-based computational method would be considered particularly beneficial in cases where empirical research is limited by the inability to conduct field trials [11] with real world settings, real subjects. There are indeed many limits to manipulate multiple independent variables through field experiments or test their effects independently. In field experiments it is difficult to create many experimental conditions. In contrast, agent-based modeling works as a virtual laboratory to conduct several "virtual" experiments in different experimental conditions. In regard, Eck and Liu [2008] stated that simulated experiments of crime prevention interventions are an important class of research methods that fits within the empirical experimental paradigm widely used in criminology. A simulation works as a computational laboratory when you manipulate a so called experimental condition by varying the values of the parameters about agents and/or the landscape [14; 18]. Modelers can use ABM to test different assumptions by designing a set of experiments (i.e., what-if scenarios) that systematically vary one aspect of the model while holding the others constant. Assuming a model is stochastic, multiple runs of each condition will produce variations in outcomes and allow the effects of chance, and uncertainty to be estimated.

There are moral boundaries to empirical experimentation that operates with human subjects that could be overcome by simulations. Crime virtual modeling might then be considered when ethical issues preclude random assignment of people to certain control conditions. For example, while police might not "strike" for long periods of time in real life, they can do so in an artificial society. Simulated experiments could also shed light on some important police functions that are very unlikely to be studied with field experiments, for example the effect of police rapid response on crime. To take an example, it would not be ethical to randomly assign people to travel through dangerous areas of a city in various states of inebriation to test the hypothesis that drunkenness increases the attractiveness of someone as a target for street robbery. Computational laboratories allow also to change the physical environment, that is not possible in real world settings.

A major problem of crime studies is that they rely on poor and misleading empirical data. Only limited data can be collected, and behavior observed, in empirical studies. For some kind of crimes, the problem of the so called "dark number" is pervasive and it implies that a certain amount of crimes are inherently undetectable. Moreover, traditional empirical methods rely on statistical models that require simplifying assumptions about human behavior and have difficulty accommodating the heterogeneity that characterizes human decision making. In contrast to them, ABM does not require simplifying assumptions about human behavior. Agents can perceive and interpret their environment, and the modeler can collect data describing agent characteristics and reasoning throughout model runs. Each agent can have different characteristics and those characteristics can change in response to variation in the agent's circumstances or decisions made. ABM specifications allow for a level of measurement precision not achievable in empirical research, through its inherent ability to investigate ''hidden phenomena'' [3]. Latent constructs in empirical research become explicit in ABM [17].

4. ABM and Crime Prevention

Criminologists have recently been exploring how agent-based simulation models can support criminal policy design. A promising use seems to be the implementation of ABM as a policy evaluation tool. In this scenario, ABM supports causal analysis by creating a counterfactual without random assignment (which often is not possible in experiments with human subject). In ABM the baseline model is the counterfactual because it represents the society modeled without some policy intervention. For example, an agent-based model which aims at studying the effects of hot spots policing on crime (Johnson 2009; Weisburd et al. 2017), after designing and running the baseline model which reproduces a random patrol strategy and collecting the outcome results, it is then possible to change the

experimental scenario, and design a hotspot deployment strategy and then let the model run again. In this way, the artificial society itself is its own counterfactual. Following this approach, it is then possible to experiment different crime prevention strategies, (i.e. testing various police patrol methods) in order to:

- plan a certain policy intervention for some kind of emergency situations (i.e. natural disasters, terrorist attacks, and mass accidents);
- investigate the effectiveness in crime prevention of various policies (social prevention interventions as well as situational ones such as guardianship;
- develop specific policing deployment strategies.

As regards criminal policy research, it was suggested how this technique could be useful to anticipate consequences accruing from one type of intervention over another and to provide a sort of pre-test of certain crime prevention programs, able to suggest any changes before their empirical test. As a consequence, simulation models can supply informed policy guidance to crime control agencies [3]. In this regard, it should be noted that the quantitative data used for processing statistics in the criminal domain only permits an ex post representation of the crime: the mapping described in this way gives us a photograph of delinquency as a static phenomenon, which can indeed be useful in terms of prevention or in the unveiling of the ways in which delinquent processes unfold, but does not offer a dynamic and articulated and generative understanding of the criminal mechanisms and the social processes involved in it.

Simulations can then be used to select the range of conditions and, in some cases, they may be usefully employed in order to screen out the least plausible innovations and to test the innovative interventions prior to implementation in the field. It could be particularly beneficial when field experiments are highly costly or to investigate situations that can not be examined using empirical research methods. For example setting experiments on three, or more, types of policing strategies simultaneously throughout the same city would be impossible in the real world. Through simulations, each experimental condition can be replicated hundreds or thousands of times and once the model has been built, further adjustments are simple to perform.

Some models have shown the potential of ABM to study how the deterrent effect of anti-crime (in particular the increase in length of the penalties) and incarceration varies between short and long term [22].

Lastly, an interesting approach in policy modelling is the so called participatory agent-based social simulation [16]. Participatory modeling aims at closely involving potential users and stakeholders in model specification, design, testing and use. The development of agent-based social simulation models is realized in conjunction with users and stakeholders. They can repeat decisions made under differing scenarios and strategic conditions. This method can provide support for decision making in a relatively cost effective way and model political negotiations between different groups of stakeholders.

5. Conclusions

In the present paper we aimed at presenting the potential intersections between Agent-based Modeling and crime research also focusing on criminal policy making issues. Agent-based Simulation is a type of computer simulation that creates a virtual society and allows controlled experimentation. Especially we refer to the use of agent-based modeling as a virtual laboratory to conduct “virtual experiments”. Simulated experiments via ABM have the potential to be a powerful tool for exploring criminological theory as they could be useful to advance, test or refine theory. A simulation helps criminologists to face the weakness of theoretical explanations because it provides a rigorous formalization of a certain theory for empirical testing and experimentation. Indeed, simulation requires that the theory’s assumptions must be operationalized as a computer algorithm that is consistent with the theory. In other words, agent-based simulation requires the researcher to specify the causal mechanisms by which a hypothesized independent variable gives rise to the dependent variable, according to the theory incorporated into the simulation model. When speaking about casual mechanisms we refer to a generative explanation of crime [4]. Unlike statistical explanations of crime, generative explanation reached through the mean of agent-based simulation focuses on the mechanisms

that give rise to the phenomenon [5]. Specifically, crime simulations allow researchers to examine not only the mere distributions of crime patterns (e.g. the dislocation of hot spots within a certain spatial environment) but also how they develop (the mechanisms that give rise to crime patterns or that prevent crime from clustering). One of the advantages of simulated experiment is its ability to create a counterfactual and to go back in time and recreate the same society upon which to apply a different intervention as an experimental scenario. In field of criminology agent-based simulation is useful in many circumstances, specifically when opportunities to conduct empirical experiments with real subjects are challenging or impossible. For example, simulations might be considered when ethical concerns prevent the random assignment of people to the so called "control conditions". Simulations are also useful as a comparatively inexpensive way to evaluate a certain program and suggest some changes before it is properly tested empirically. The cost of running 'virtual' experiments is inferior of the costs involved in empirical field trials. Simulation may play a significant role in vetting and strengthening programs prior to their empirical testing. Within criminology, ABM has been usefully employed to projecting the likely impact of crime prevention interventions and to evaluating the potential of a certain criminal justice policy strategy. As far the application of crime simulation to policy making, several researchers have been developing agent-based models to study policy problems in different policy sectors and with different purposes. Agent-based social simulation can support the overall policy making process along its different stages and through formalization which reveals logical inconsistencies of a theory that must be eliminated before planning useful policy interventions. If crime prevention interventions can be simulated, then we may be able to weed out interventions prior to their application in the field for empirical testing. Several agent-based models address this question and allow for the examination of the outcomes of different crime prevention interventions (i.e. police patrolling strategies).

Moreover, simulations could reveal how much time must pass between the implementation of a policy intervention and the appearance of its outcomes, for example in terms of crime reduction or increase of the safety of the population. This means that simulation helps us to measure the impact of a policy intervention. This could also allow to improve the planning of empirical experiments and avoid using experiments that measure impact prior to its occurrence. Finally, simulations could help us estimate the conditions in which a certain intervention is likely to wear off. It is then possible to use simulate experiments to estimate the total impact of the intervention, by using various experimental scenarios in which you manipulate parameters related to the social, cultural or economic environment in which the policy is implemented and then to observe the consequences in the model. It may allow to give realistic measures of a program's impact and to provide effective, reliable, and replicable instruments for evidence-based policy making.

The current debate about the limitations of the ABM approach to crime research regards predominantly the lack of model details that sometimes makes it difficult to assess where sufficient evidence exists to support a model; the transparency with which researchers describe the rationale for the choices they make during model design and implementation [10]). The incorporation of empirical knowledge to asses the parameterizing and calibration of the models is needed in order to inform both theory and practice. The discussion here is not intended to argue that ABM is better than traditional empirical methods in criminology, rather that it can play a valuable role as part of a research program utilizing a variety of methods [3; 9]. ABM should inform empirical crime research and vice versa.

6. References

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