

Beyond the State of Nature: Introducing Social Interactions in the Economic Model of Crime

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The standard economic model of crime emphasizes the individual rationality and agency of criminals, while sociological theories typically emphasize the importance of social forces. This essay surveys a recent strand of literature on law enforcement that bridges these two approaches. Using the tools of game theory, it investigates crime as the outcome of the interaction between rational individuals. The survey shows that this analysis leads to a substantially richer set of hypotheses regarding the effect of enforcement than the standard economic model, depending on the classification of the social context, or game, in which agents operate. In doing so, it brings rational choice theories in line with long-standing insights in the field of criminology, as well as providing new analytical distinctions and generalizations.

“[A] useful theory of criminal behavior can dispense with special theories of anomic, psychological inadequacies, or inheritance of special traits and simply extend the economist’s usual analysis of choice.” ~ Gary C. Becker (1968:170)

“If we do not even bother to sort out the many different ways in which people (and other animals) are moved, how can we hope to have an adequate descriptive, much less a normative, theory?” ~ Martha Nussbaum (1997:1210)

1. INTRODUCTION

The economic model of crime forms the backbone of the discipline of law and economics. First formalized by Becker (1968), it holds that a potential criminal rationally weighs the costs and benefits of crime. The main policy implication of this model is that the government can increase efficiency by imposing costs on the perpetrators of crime. If these costs are high enough the model predicts that people will rationally abstain from crime. Thus, the

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higher the formal sanctions imposed by the government, the lower crime will be, a prediction known as ‘the deterrence hypothesis.’

In its most basic version, the standard economic approach abstracts from social influences in modeling the costs and benefits of crime. This reductionism has invoked criticism from criminologists and other social science practitioners over the last half century, as discussed by Hirschi (1986). One main criticism is that criminal and anti-social behavior are produced in social interactions, and that criminal behavior can often not be understood without knowledge of the social background in which it originates (Meares et al., 2004). As I will show in the next section, skepticism about the empirical relevance of the deterrence hypothesis has made criminologists reluctant to embrace the economic model, and some commentators have even challenged the usefulness of rational choice theories in crime research altogether (Akers, 1990; Doob and Webster, 2003).

However, deterrence theory has not been frozen since Becker’s contribution. Within the field of criminology, much progress has been made over the past decades to bring social context into the analysis of deterrence (e.g. Zimring and Hawkins, 1973; Sherman, 1993; Posner, 2000; Fagan and Meares, 2008). This research has provided qualifications to the general deterrence hypothesis, and has shown that social context and informal incentives matter for the effectiveness of legal enforcement.

Recently, a similar development has occurred within the field of economics. Criminal or anti-social behavior is increasingly modeled as the result of the interaction of individuals in society, using the tools of game theory. Game theory is the branch of rational choice theory that deals with the strategic interaction of individuals. Its most common solution concept is the ‘Nash-equilibrium,’ which describes a situation where everyone behaves optimally given the behavior of others. By analyzing crime as a Nash equilibrium of the relevant game, the game theoretic approach assumes rational behavior, but in an explicitly social context. This literature thus provides an appealing synthesis between (sociological) theories of crime that stress social influence, and approaches that emphasize individual agency.

The main aim of this essay is to provide an overview of this new literature, and show its relevance to mainstream topics in criminology such as peer effects, police crackdowns, and the policing of markets for illegal substances. The organizing question in this endeavor is how different kinds of social interactions affect the impact of enforcement policies. Thus, rather than reviewing all models of crime, I restrict my review to those studies that explicitly investigate law enforcement strategies in the presence of social

interactions.¹ In the models I will discuss, the effect of enforcement is evaluated not simply by its effect on the payoffs of individuals acting in isolation, as in the standard economic theory of crime. Rather, the analysis is concerned with the way enforcement changes equilibria in the underlying game and the associated behavior.

I survey the impact of enforcement in the presence of peer effects, stigmatization, and the interaction of criminal cartels. I also investigate how the existence of formal enforcement institutions affects the formation of relevant preferences for either criminal or cooperative behavior. Researchers have studied this question in the context of evolutionary games.

This exercise brings several new insights. First, the use of a formal analytical framework brings new distinctions and generalizations to the existing literature. Specifically, game theory has a rich conceptual framework to classify and distinguish different kinds of social interactions. I will discuss coordination games, signaling games, market interactions, and evolutionary games among others. This allows a systematic evaluation of enforcement efforts, depending on the strategic environment that agents are facing.

Second, the analysis shows that the straightforward connection between higher penalties or stricter enforcement and lower crime suggested by the standard economic model, disappears when social complexities are introduced. It turns out that, conditional on the type of game, formal sanctions may either be more effective or less effective than the standard economic framework predicts. In some games, social multipliers exist that amplify the deterrent effects of formal enforcement. In other contexts, social forces will counteract these effects and may even lead enforcement to be counterproductive. This shows that formal rational choice models can go beyond the standard deterrence hypothesis, and are compatible with the criminological and sociological literature mentioned above.

The article is organized as follows. In Section 2 I first briefly introduce the standard economic theory and then survey the debate on its empirical relevance. In Section 3 I turn to the game theoretic approach to crime and show how different kinds of interactions affect the effectiveness of enforcement measures. Section 4 concludes.

2. THE STANDARD MODEL

“Let us return again to the state of nature, and consider men as if but even now sprung out of the earth, and suddenly (like mushrooms), come to full maturity, without any kind of engagement with each other.” ~*Thomas Hobbes* (1949[1642]:100)

A starting point of the economic literature on crime is that in the absence of formal authority, many people would steal, kill and do other nasty things. This is inefficient, because the costs of such behavior to the victims outweigh the gains to the perpetrator. Therefore, everybody would be better off if some authority could force people to abstain from such inefficient actions. This idea goes back to at least 1651, when the philosopher Thomas Hobbes (1588-1679) argued that in the absence of authority, humans would find themselves in a “state of nature” in which there would be a continuous “war of every man against every man.” For Hobbes, the way out of the state of nature was to cede power to a central authority or ‘Leviathan,’ who could use this power to deter potential evildoers (Hobbes, 1994[1651]).

This view can be translated to game theoretic terms as saying that people in society play a Prisoner’s Dilemma. In this archetypical game, players face the choice to cooperate or defect. The structure of this game is such that each player can increase her utility by defecting against the other player(s), regardless of what the other player does. In other words, defection is a *dominant strategy*. All rational players therefore defect in equilibrium, and aggregate welfare is lower than if—perhaps forced by a Leviathan—they coordinated on mutual cooperation.

The economic literature on crime has continued this theme. In his seminal contribution, Becker (1968) assumes that people rationally decide to commit crimes on the basis of the costs and benefits. To be more precise, Becker writes that “a person commits an offense if the expected utility to him exceeds the utility he could get by using his time and other resources at other activities” (1968:176). In this standard framework, the criminal chooses his criminal activity to maximize the following expected utility function

$$EU_j(c_j) = c_j[p_j U_j(Y_j - f) + (1 - p_j)U_j(Y_j)] + (1 - c_j)\bar{U}_j, \quad (1)$$

where $c_j \in \{0, 1\}$ is an indicator variable that takes the value of 1 if individual j commits an offense, and p_j is the probability of getting caught; $U_j(\bullet)$ is his (Bernoulli) utility function; Y_j is the benefit (monetary plus psychic) from an offense; and f is to be interpreted as the (monetary) cost of crime due to punishment. \bar{U}_j is the value of the outside option of not committing crimes, such as the wage that could be earned in the legal sector. In this simple form, the deterrence model says that the attractiveness of crime depends on policy parameters p_j , f and on the benefit from crime Y_j and outside option \bar{U}_j . Specifically, Becker shows that an increase in the probability of detection or the penalty reduces the expected utility of crime. On aggregate, this will decrease the number of crimes, a prediction known as

the ‘deterrence hypothesis.’

Why would an authority want to engage in deterrence? Becker assumes that, like defection in the Prisoner’s Dilemma, crime leads to an inefficient situation, because the cost of crime to the victim is often higher than the benefit to the perpetrator. Following Hobbes, Becker shows that the government can increase efficiency by enforcing penalties for criminal activities, thus coordinating behavior on a better, Pareto-dominant, equilibrium. Both Becker (1968) and Stigler (1970) derive several properties of the socially optimal incentive scheme, such as an emphasis on fines, and the implementation of larger penalties for crimes that lead to a larger gain for the criminal.

Becker’s theory thus extends “the economist’s usual analysis of choice” (1968:170). Its simplicity and elegance have made it a paradigmatic framework that has become almost synonymous with the economic literature on crime (see Polinsky and Shavell (2000) for an overview). On the empirical side, however, there is no consensus on the validity of the standard model and the associated deterrence hypothesis, despite an enormous research effort in the last decades. It is instructive to reflect for a moment on why this is the case.

2.1. *Does Legal Enforcement Deter Crime? A Bird’s Eye View*

The literature on the deterrence hypothesis is so large that I cannot hope to survey it here, so I will restrict myself to general remarks. To start with, in situations where social interactions are absent, the model seems to predict relatively well. For example, in a laboratory experiment, where all social interactions can be excluded, Harbaugh et al. (2011) corroborate the deterrence hypothesis.² In the real world, however, there is little consensus as to whether the empirical literature has demonstrated a deterrent effect of enforcement. Consider the conclusions of two recent survey articles.

“[R]esearchers have enjoyed significant progress in recent years in testing the economic model. They have found that deterrence has a substantial but far from complete role in explaining observed patterns of criminal activity.”

~*Levitt and Miles* (2007:457)

“Does criminal law deter? Given available behavioral science data, the short answer is: generally, no.”

~*Robinson and Darley* (2004:173)

Disagreement is not limited to these two survey articles. While an influential survey by Nagin (1998) gives qualified support to the deterrence hypothesis, Doob and Webster (2003), in a study titled “Accepting the Null,” argue that

the empirical literature has by now convincingly demonstrated that there exists no consistent effect of increased penalties. Donohue (2007) provides thought-provoking evidence both for and against the deterrence hypothesis, and argues that the severity of sanctions matters less than their certainty.

It is somewhat puzzling that decades of intensive empirical research on the deterrence hypothesis have not yielded consensus. One reason may be that we still have not looked hard enough, or nature has not given us clear enough evidence. Furthermore, the different conclusions reflect the bewildering range of studies in which both sides of the debate can find plenty of evidence for their positions, as well as different takes on methodological and statistical issues.

More fundamentally, however, there may be something wrong with the question people are trying to answer. Note that although their conclusions diverge, the reviews cited here share the same point of departure. They implicitly assume that there is such a thing as *the* effect of legal sanctions and enforcement. That is, sanctions either deter or they don't, and in doing so they either corroborate economic theory or falsify it.

The dangers of such overgeneralization are easy to find in applications of empirical deterrence research. One example is the discussion over the empirical effects of laws that allow carrying concealed handguns. In theory, allowing people to do so should have a deterrent effect, because criminals know that their victim may be armed. In a controversial study, Lott and Mustard (1997) investigate the introduction of right-to-carry laws using a panel dataset with county-level data. They present evidence that concealed handguns have a significant deterrent effect on various crime categories. However, their results have been sharply criticized by a number of authors. Dezhbakhsh and Rubin (1998) show that in a more general model where the effect of right-to-carry laws is allowed to influence the effect of the control variables, their impact is much smaller and no longer goes in one direction for all crime categories. Similarly, Black and Nagin (1998) show that the effect of handgun regulation is very different across states and crime categories, and no uniformly negative effect on crime can be found.

Another example is the introduction of the LoJack security system for cars. LoJack is invisible from the outside and allows for tracing of the stolen vehicle, substantially raising the probability of apprehension of the perpetrators. Ayres and Levitt (1998) find that it reduced auto thefts by as much as 50% when it was implemented in the US. However, Gonzalez-Navarro (2008) studies the effectiveness of the device in Mexico, where it was only introduced in certain states. He shows that the reduction in

thefts in those states was matched almost one-for-one by an increase in theft in neighboring states where LoJack was not introduced.

These examples highlight that there is no such thing as *the* effect of deterrent policies. Rather, they seem to work in some times and places, while not in others. Nagin (1998:1) is therefore right to stress that “[i]t is important to understand better the sources of variation in response across place and time” (see also Sherman, 1992). The challenge for theorists is to explain the characteristics of the environment in which enforcement can be expected to have an effect. The rest of this article shows how the framework of game theory can be useful in this regard.

3. CRIME AND SOCIAL INTERACTIONS

“The desirability of a proposed legal rule, then, does not depend only on the existence of a collective action problem on the one hand, and competently operated legal institutions on the other hand. It also depends on the way nonlegal arrangements already address that collective action problem and the extent to which legal intervention would interfere with those nonlegal systems.”

~Eric Posner (2000:4)

Its disappointing empirical performance has led many to criticize the economic model of crime. However, we should be careful not to throw out the baby with the bathwater. My first aim in this section is to discuss formal approaches that enrich the standard model by embedding it in a social context. By “social context” I mean that the agents in society are engaged in some kind of social interaction that gives rise to crime or other forms of anti-social behavior. I categorize these interactions according to both their social context and the structure of the game that agents are playing. In turn, I discuss peer effects, illegal goods markets and organized crime, interactions between enforcement agencies and criminals, and the cultural evolution of preferences. The analysis of game theory is concerned with finding equilibrium behavior in these interactions: situations in which all actors maximize their payoffs, taking the behavior of others as given.

My second aim is to sketch the implications of these models for policymaking, specifically with respect to the existence of deterrent effects of enforcement. In each case, I analyze how enforcement changes the equilibria of the underlying game.

Two disclaimers are in order. First, in most of the article, I treat at least some enforcement variables as exogenous. Only in section 3.3 do I investigate models where there is a feedback effect of criminal behavior on

enforcement variables. Second, with some abuse of language I use “enforcement” or “legal enforcement” to refer to policy initiatives that increase either the severity of the sanction or its certainty. Except when the distinction is important, I will lump the latter two policy instruments together.

3.1. PEER EFFECTS

There are a large number of empirical studies showing that peer effects, such as conformism, imitation or stigmatization, are a pervasive influence on crime decisions. Overviews of empirical evidence are given in, e.g., Grasmick and Green (1980), Grasmick and Bursik (1990), Glaeser et al. (1996), Kahan (1997), and Patacchini and Zenou (2011).

Glaeser et al. (1996) demonstrate how important these effects can be. The study shows that most of the variance in crime rates cannot be explained by observable characteristics of neighborhoods, residents or policies. Using data from 1980, they show that on a cross-country level, the United States has about 150 times the homicide rate of Japan. On an intra-country level, Atlantic City, New Jersey has about 400 times the crime rate of nearby Ridgewood Village. And on an intra-city level, the 1st Precinct in New York City has about 10 times the crime rate of the 123rd Precinct. In the case of New York, the authors show that no more than 30% of these differences can be accounted for by observable differences between different locations (e.g. levels of income, schooling, female-headed households, arrest rates, etc.). The authors propose that these differences arise from social norms and other peer effects.

Below I classify the literature on deterrence and peer effects according to the game theoretic structure of the social interaction. I will first focus on theories that model peer effects as complementarities, and then discuss in some more detail (signaling) models of stigma and reputation.

3.1.1. *Peer Effects and Complementarities*

Many kinds of peer interactions generate complementarities in criminal behavior. Examples are conformism, imitation, the transmission of crime techniques, and learning about criminal opportunities. Another important source of complementarities is informal or community-based sanctions against criminals. When there are more criminals, these sanctions are less potent because there are less people to apply sanctions to a bigger group of offenders. In all of these cases, crimes becomes more attractive if there are more criminal peers around.

Most theoretical papers that study such complementarities use a variation of the following extension on the standard model

$$EU'_j(c_j) = EU_j(c_j) - S(c_j, n, \theta_j), \quad (2)$$

where $EU_j(c_j)$ is the expected utility of the crime decision as defined in (1), and $S(\cdot)$ represents an additional social or psychological cost of crime to the criminal. This cost depends on the individual's crime decision c_j , the fraction of the population that commits offenses n , and a parameter θ_j which measures the moral costs or other sources of aversion to crime to the agent. Agents differ with respect to θ_j , i.e. they are distributed over the type space according to some distribution $F(\theta)$. Although different papers assume different functional forms for $S(\cdot)$, the typical assumption is that the social cost of crime $S(1, \theta_j, n) - S(0, \theta_j, n)$ is decreasing in n . Thus, the more people engage in crime, the lower the social costs of doing so. A common terminology is to associate the (equilibrium) level of n with a 'social norm,' because it measures the degree to which crime or compliance is 'normal.'³

Examples of this model-framework are Weibull and Villa (2005), Funk (2006), and more informally, Cooter (1998). In the context of tax evasion, where peer effects are especially important, models using variations of (2) have been proposed by Gordon (1989), Myles and Naylor (1996), Kim (2003), Fortin et al. (2007) and Traxler (2010). A more recent approach is to model interaction effects using graph theory. This allows for a more specific modeling of the topologies of interactions in the form of a social network (Ballester et al., 2006, 2010; Patacchini and Zenou, 2011).

Whatever the exact source of complementarities, the implication of these models is that peer effects turn crime into a *coordination game*⁴ with both high and low crime equilibria. In equilibria with high crime levels, it is rational for many people to engage in crime because peer effects and social norms inhibiting crime in the community are weak (social enforcement). In equilibria with low crime levels, the reverse holds.⁵

Complementarities and Enforcement – What are the implications of such models for optimal enforcement? In a Nash equilibrium, the action of each individual is optimal given the expectations that she has about the actions of others. In coordination games, different equilibria are associated with different sets of expectations. Policy-makers who want to change the prevailing equilibrium thus have two options: they can either try to influence behavior directly, or try to shift behavior indirectly by changing expectations.

Think about the decision whether to drive left or right on the road. This is an example of a pure coordination environment, in which the *only* thing that matters for an individual's behavior is his or her expectations about the behavior of other individuals. The so-called *focal point theory of law* (McAdams, 2000) holds that laws help people to coordinate the expectations they have about each other's behavior, and thereby the behavior itself. More specifically, laws may create *focal points*, salient courses of action that people expect others to follow. Law is well positioned to do so because of its unique regulatory role that can induce (near) common knowledge of expectations. To create a focal point, such as driving on the right side of the road, penalties do not have to be large, they just have to give a small incentive that makes a particular equilibrium salient. In this way, 'mild laws' that do not significantly alter the payoffs of the game may nevertheless cause large shifts in behavior. Although it is difficult to test the channels of belief formation in the real world, there is some evidence from the laboratory supporting the claim that laws with little or no enforcement can be effective through their coordinating role (Bohnet and Cooter, 2003; McAdams and Nadler, 2008).

Most situations are not pure coordination games, because some people will always prefer to commit crimes in the absence of formal or informal sanctions. In such games, the multiplier effect of deterrent policies may be less pronounced, but still positive. As long as the social cost of crime $S(1, \theta_j, n) - S(0, \theta_j, n)$ increases if n falls (as assumed above), increased enforcement does not just raise official deterrence, but also strengthens informal mechanisms against crime. This means that relatively small increases in enforcement strength may have a multiplier effect as they cause expectations to shift and induce coordination on a new equilibrium with a lower crime rate (Funk, 2006; Traxler, 2010). In other words, if the system is close to a tipping point, even temporary increases in deterrence can have lasting effects (see also the discussion on congestion and crackdowns in Section 3.3 below).

Ballester et al. (2006) use graph theory to show how the multiplier may depend on the structure of a criminal network. They define a measure of the centrality of each player in the network, based on the direct and indirect links of each player. Perhaps unsurprisingly, they show that enforcement is most effective if it focuses on the player with the largest centrality index (the 'key player'). Ballester et al. (2010) show that the effectiveness of enforcement increases more than proportionally with the centrality index. The reason is that by removing the key player, players who used to be connected through the key player will no longer be so.

Expressive Law – Another way in which deterrent policies may change beliefs and cause multiplier effects is through the information they convey about the values in society. According to theories of *expressive law*, laws can have an important role in this respect. In large groups, people are often uncertain which values others entertain and which actions will invoke anger or stigma (Kahan, 1997). Provided people believe that the law reflects public opinion, the introduction of a law makes it common knowledge which actions are subject to stigma and the disapproval of others (Sunstein, 1996; Cooter, 1998).

As in the focal point theory of law, this implies laws can have large effects without being enforced by large penalties. In other words, inducing different expectations about the attitudes of others can lead to different self-fulfilling equilibria in coordination games. As examples, Cooter (1998) mentions “pooper-scooper” laws and no-smoking signs at airports as examples of laws that function largely without formal enforcement. Funk (2007) provides field evidence that supports the existence of expressive effects. She shows that repealing a mandatory voting law in Switzerland had a large impact on turnout, even though the law had barely been enforced. Tyran and Feld (2006) and Galbiati and Vertova (2008) provide laboratory evidence for expressive effects of law.

Note that theories of expressive law assume that people expect others to support the law and are willing to enforce it informally. However, this need not be the case. The introduction of sanctions may also be a signal that others are in fact not behaving well, which may reduce expectations of informal enforcement and increase crime or anti-social behavior. These kinds of effects occur when the authority has more information about aggregate behavior than the individuals in society. For example, a crackdown on immigrants may have a stigmatizing effect and lead people to think that immigrants must have bad intentions. Sliwka (2007), Van der Weele (2012) and Bénabou and Tirole (2011) provide formal models of this phenomenon, and show how the signaling effect may induce the authorities to set lower sanctions in equilibrium. Cialdini (2007) provides field evidence, Galbiati et al. (2011) show the relevance of this phenomenon in the laboratory.

3.1.2. Reputation and Stigma

Considerations of stigma, reputation and status are of fundamental importance to the decision (not) to commit crimes. Stigma has been analyzed in a reduced form way in some of the studies cited in the previous subsection. To investigate these concerns more explicitly, theorists have modeled crime in the context of a signaling game. In signaling games, one

party has private information about his or her own characteristics, or ‘type.’ Some types of agents (for example strong, smart or altruistic types, depending on the context) can benefit from making this information public. They can do so by sending credible ‘signals,’ actions which are too costly to mimic for other types.

A signaling model enhances the utility function of the standard model in the following way

$$EU_j''(c_j) = EU_j(c_j) - g(\theta_j)c_j + \mu E[\theta_j | c_j], \quad (3)$$

where $EU_j(c_j)$ is the expected utility of crime as defined in (1) and $g(\theta_j)$ denotes an additional cost of crime, which depends on the ‘type’ of agent θ_j . $E[\theta_j | c_j]$ is the public’s expectation of person j ’s type, based on her observable crime decision. This expectation is formed rationally in equilibrium.⁶ The importance of reputation to person j is captured by the size of the parameter μ . Signaling models using variations⁷ of (3) are Bénabou and Tirole (2006, 2011) and Dur and Van der Weele (2011). Silverman (2004) provides a somewhat different matching model of signaling and crime. Posner (2000) provides an extensive informal discussion.

Bénabou and Tirole (2011) provides a signaling-based explanation of pro and anti-social behavior. In their model, a ‘type’ is defined as the degree of ‘altruism’ or pro-sociality of the agent. The corresponding assumption is that $g'(\theta_j) > 0$, i.e. a higher type has higher costs of behaving anti-socially because she has stronger moral values. Bénabou and Tirole (2011) analyze a separating equilibrium in which only the lowest types engage in anti-social behavior, and thereby suffer loss of reputation or stigma. This reduces utility, for example because having a criminal record means that it is harder to get a job (Rasmusen, 1996). Thus, in this model, image concerns reduce the amount of crime that would otherwise occur.

Dur and Van der Weele (2011) apply a variation of (3) to model a violent inner city environment. Here, ‘type’ θ_j refers to the ‘toughness’ of the individual j . The assumption is that $g'(\theta_j) < 0$, because a tougher or more fearless type suffers less when committing a crime. People derive utility from being perceived as ‘tough,’ because this scares potential adversaries and helps them to survive in a violent environment. Thus, in this model, the competition for reputation increases crime. There is ample evidence that criminal acts are committed for such reputation-building purposes. For example, Anderson’s *Code of the Street* (1999) claims that violence and criminality can earn respect from peers. Dur and Van der Weele (2011) and

Fagan and Meares (2008) cite more ethnographic evidence. The signaling motive for crime can also explain why many crimes in inner city neighborhoods are conducted in the presence of witnesses (Silverman, 2004).

Reputation and Legal Enforcement – The reputation motive for crime interacts with legal enforcement in subtle ways. In general, by introducing penalties for deviant behavior or rewards for good behavior, authorities alter the (separating) equilibria of the game that agents are playing, and thereby the stigma or reputation associated with criminal activities (Posner, 2000).

First, suppose that crime carries a negative stigma, as in the model of Bénabou and Tirole (2011). Harsher penalties for offenders will make it more costly to use crime as a signal, and lead to less offenses. Again, there is a social multiplier associated with sanctions which can either reinforce or inhibit the effect of enforcement, depending on whether sanctions increase or decrease the amount of informal stigma. Moreover, the authors show that the socially optimal incentives are lower than in the absence of reputation or status concerns. The reason is that reputation concerns introduce a socially wasteful component to the compliance decision, since the rise in the relative status of one person reduces the relative status of the others. Thus, in comparison to the standard model, the authority will provide lower incentives in order to compensate for this ‘over-investment’ in compliance.

Dur and Van der Weele (2011) assume the possibility of engaging in crimes of different severity (no crime, minor crime, or severe crime). They show that changing enforcement or deterrence for a particular crime will induce subtle substitution effects. In particular, a zero-tolerance policy that cracks down on minor offenses may actually reduce both minor offenses and serious crimes. Relatively wimpy types are discouraged from signaling, which raises the signal of toughness sent by committing minor crimes. In other words, the status associated with defying the police increases with sanctions. This makes minor crimes more attractive to the tough types at the top of the hierarchy, causing some of them to switch from severe to minor crimes. In other words, there is a ‘double-dividend’ from deterring small crimes, because cracking down on a particular crime disturbs the wasteful ‘rat race’ of criminal signaling behavior. This may constitute an explanation for the controversial ‘broken-window-effect,’ the empirical phenomenon that cracking down on minor signs of disorder (broken windows) also tends to reduce more serious crimes (Kelling and Coles, 1996; Braga and Bond, 2008).

However, increasing enforcement may also backfire in signaling environments. Bénabou and Tirole (2006) present a signaling model where pro-social behavior is used to signal altruism as well as a disregard for money.

When incentives are introduced, people who care mostly about money will now also start behaving pro-socially, which dilutes the signal associated with pro-social behavior. This may lead the agents with intermediate motivations for altruism and money to stop signaling, possibly resulting in a net crowding-out of pro-social behavior in equilibrium. If offenses are committed in order to signal 'toughness,' Dur and Van der Weele (2011) show that raising penalties for severe crime rather than minor crimes may cause spill-over effects and raise the total amount of crime. The reason is that some relatively tough individuals will now commit minor crimes. This raises the status associated with minor crimes, and attracts new (relatively wimpy) criminals. Silverman (2004) argues that police arrests and court proceedings that increase the visibility of crime, will involuntarily strengthen the signaling benefits of offenses committed to signal toughness.

Stigma as a Policy Variable – The last paragraphs have shown how legal enforcement may influence informal stigmatization in equilibrium. Authorities can also influence the degree of stigmatization more directly, for example by publishing (or not) the names and addresses of offenders, or providing criminal records to employers. Benábou and Tirole (2006) argue that such a policy is likely to have decreasing returns to scale for the same reason as do conventional policies. Inducing compliance by less pro-socially motivated individuals lowers the signal of virtuous behavior associated with compliance.

A few papers have provided formal models of stigmatizing policies in the context of the labor market. Rasmusen (1996) provides a simple model in which providing criminal records to employers increases deterrence of crime. However, Funk (2004) shows that if one includes the possibility of recidivism in the analysis, the positive effects of disclosure policies are not so clear. High stigmatization means that ex-convicts have low opportunities in the legal sector, and are more likely to repeat their offenses. Given the complexity of this issue, more research in this area is required.

Summing up, the presence of social interactions means that there are multiplier effects of policies or events that reduce the crime rate. Insofar as informal mechanisms against crime are stronger when crime is low, informal mechanisms increase the effectiveness of formal policies. However, informal mechanisms may also reduce the effectiveness of deterrent policies, if these policies send the message that non-compliance is widespread, or raise the visibility of offenders in communities where crime confers status.

Two empirical papers estimate the multiplier stemming from peer effects and congestion. Rincke and Traxler (2011) investigate the effectiveness of

TV-license audits in Austria, and find that on average, three detections make one additional household comply with the law. Their data suggest that word of mouth is the most likely mechanism for this spillover in enforcement. Galbiati and Zanella (2012) use regional data on Italian taxpayers. They find a larger multiplier of about 3, meaning that any shock that increases tax compliance initially by 1%, will reduce it by about 3% in the long run, when a new equilibrium is established. Their data are consistent with both peer effects and enforcement congestion (see below) as being the cause of this multiplier effect.

3.2. ORGANIZED CRIME AND MARKETS FOR ILLEGAL GOODS

Much criminal behavior is conducted by highly organized and competing international criminal organizations. The most prominent case is the sale of illegal narcotics. In 2003 the United Nations Office on Drugs and Crime estimated the global market for illegal drugs at \$321.6 billion, or 0.9% of world GDP.

In the context of the U.S. ‘war on drugs,’ sentences for drug trafficking and the resources devoted to combatting criminal gangs increased manyfold over the last decades. Mansour et al. (2006) document that the budget allocated to the Drug Enforcement Administration rose from \$0.07 billion in 1973 to \$1.55 billion in 2000. As a result of the Kingpin Act, sanctions for drug trafficking have also substantially increased.

The idea behind these measures was that increased enforcement would deter supply, raise prices and lower consumption. Instead, the opposite has happened. Despite the greatly increased resources devoted to enforcement, the price of cocaine and heroin decreased by about a factor of 5 between 1980 and 1996, and the consumption of illegal drugs went up significantly in the 1980s. These facts pose a major intellectual puzzle, and suggest that deterrent strategies have backfired in the context of the war on drugs. To explain this it is necessary to analyze in more detail how enforcement affects the interaction between criminal organizations.

3.2.1. *Law Enforcement and Organized Crime*

An implicit assumption underlying the deterrence view is that the market structure does not change in response to increased enforcement measures. In reality however, increased deterrence may lead to a fragmentation of suppliers, more competition, and lower prices. This argument dates back to Buchanan (1973). He suggested that if products are a ‘bad’ instead of a ‘good,’ they are best provided by a monopolist, who has an incentive to keep

prices high and limit supply. Prosecution of the illegal activities of such a monopolist may instead increase competition and output.

Buchanan's idea has been taken up and refined by Mansour et al. (2006) and Poret and T ej edo (2006). They model the market for illegal drugs as a game between an endogenous number of suppliers that are engaged in (Cournot) product competition. The crucial assumption is that the detection probability of a supplier increases with its relative size. Under this assumption, stronger enforcement has ambiguous effects. Although increased sanctions decrease drug production for a given number of suppliers as the standard model predicts, they also discourage the concentration of market power. As a result of increased enforcement, entry occurs (Poret and T ej edo, 2006) or suppliers break up (Mansour et al., 2006). The increase in the number of suppliers intensifies competition and increases output. Mansour et al. (2006) show that the end result may be more supply and a lower market price. The authors argue that this is what happened after increased enforcement dissolved the Medellin and Cali drug cartels: the number of criminal organizations involved in the production of cocaine increased, and this was eventually translated into an increase in total production.

In effect, if criminals compete in the production of crime in cartel-like structures, enforcement operates as a crude form of antitrust. Like antitrust, enforcement may increase competition and production, lower prices and stimulate consumption. However, in the context of criminal activities, this is the exact opposite of the intentions of the policy-maker.

While the aforementioned papers study the horizontal structure of the drug market, Poret (2003) examines the impact of enforcement on the vertical structure of drug supply lines. She assumes that supply lines consist of traffickers (upstream) and dealers (downstream). Poret shows that if enforcement concentrates on dealers, who are easier to catch than the traffickers, dealers will raise their profit margins to compensate for increased transaction costs. However, this will induce traffickers to lower their prices in order to protect their market share. The net effect may be lower rather than higher prices, and an increase in consumption.

In summary, tighter enforcement may change the organization of the supply of illegal goods in ways that trump the intentions of policy-makers. The costs associated with the war on drugs show how important such considerations can be. In this regard, it is particularly welcome that economists are turning towards the modeling of organized crime and gang behavior.

3.3. ENDOGENOUS ENFORCEMENT

So far, we have studied how exogenous variations in enforcement levels affect the crime rate. In reality, enforcement strength is not exogenous, but determined by feedback effects between society and enforcers and social processes within the enforcement agencies themselves. In this section, I will discuss models in which the crime level n and the enforcement instruments are determined simultaneously in equilibrium. Most research has focused on the endogeneity of the detection rate p , with the level of the penalty f remaining exogenous. With respect to the standard model, this amounts to the endogenization of the detection rate p with respect to the crime rate n and the penalty, i.e. $p = p(n, f)$. The literature on such ‘endogenous enforcement’ is rather large, so I only present some of the most prominent ideas here (McCarthy (2002) presents a useful survey with further references).

With respect to the crime rate n , there are many possible feedback effects on enforcement. Bar-Gill and Harel (2001) discusses several of those, and argues that higher crime rates may lead to either higher or lower levels of deterrence. For example, economies of scale in law enforcement and prosecution methods can lead enforcement to be more effective when crime is high. However, the reverse effect has received more research attention, especially a mechanism called ‘congestion,’ or ‘enforcement swamping.’ The more people commit crimes, the more this stretches the resources of the criminal justice system, and the lower the probability of arrest. Thus, the effectiveness of formal enforcement decreases in the crime rate, giving rise to complementarities similar to those associated with informal mechanisms and social norms in Section 3.1. Models of congestion (Sah, 1991; Schrag and Scotchmer, 1997; Ferrer, 2010) thus also predict the existence of multiple equilibria. That is, for a given level of enforcement resources, there may be a high crime equilibrium with ineffective enforcement and a low crime equilibrium with effective enforcement.

When we turn to the effect of penalties f on the detection rate, a prominent strand of literature has developed around the ‘inspection game.’ In this game the players consist of an enforcement authority and a potential criminal or agent. The enforcement authority chooses a level of costly monitoring (either high or low), and the potential criminal simultaneously chooses whether to engage in crime or not. The fact that choices are made simultaneously distinguishes this model from most others in this survey, where the enforcement authority first sets an enforcement level to which individuals react. The inspection game does not have a pure strategy

equilibrium, because the enforcer prefers a high level of monitoring only if the agent engages in crime, whereas the agent only engages in crime when there is low monitoring. Consequently, the only equilibrium is a mixed strategy equilibrium, in which the enforcer chooses high monitoring only with some probability. Tsebelis (1989, 1990) points out that such an equilibrium has some counterintuitive implications. Most interestingly, in equilibrium the size of the penalty does not influence the probability with which the agent engages in crime. The reason is that the authority reacts to a lower propensity to choose crime by lowering the probability of monitoring in such a way that it exactly offsets the effect of the increased penalty.

Both the validity of the assumptions underlying the inspection game, and the robustness of its predictions have been criticized (Pradiptyo, 2007). However, the central point that different policy instruments are not independent from each other is made by other authors, using at least two different approaches. First, courts and juries care about the consequences of mistakenly convicting an innocent person (Andreoni, 1991; Fees and Wohlschlegel, 2009). Consequently, if penalties increase, courts and juries will be more reluctant to convict, implying a lower level of deterrence overall.

Second, higher penalties may increase corruption in the legal system. Basu et al. (1992) assume that criminals can bribe policemen in order to lower the detection or conviction probability. They show that a higher penalty increases bribery efforts by criminals, since there is more incentive to evade a high penalty than a low one. As a result, higher penalties are less effective than the standard model predicts, a result that is robust to many modeling variations (see Kugler et al. (2005) for a short survey). Bowles and Garoupa (1997) argue that higher fines may potentially even lead to higher crime rates. Kugler et al. (2005) show that the bribing activity of criminal organizations will react more strongly to increased penalties when the institutional structure is weak and law enforcement officials are badly paid. Buscaglia (2008) presents empirical evidence consistent with the idea that higher penalties increase corruption.

3.3.1. *Implications for Optimal Deterrence*

The models discussed in this section offer explanations for some important features of real world deterrence mechanisms that are not predicted by the standard model: the reluctance to rely on extremely high penalties and the use of police crackdowns.

In his seminal paper, Becker (1968) discusses the conditions under which the penalty and the detection probability are substitutes in achieving deterrence. He shows that if criminals are approximately risk-neutral, the penalty and the detection rate are perfectly substitutable. Thus, in principle,

deterrence could be generated cheaply by substituting (costly) detection rates for (cheap) penalties. The literature cited above shows that higher penalties do not necessarily translate into higher deterrence. Instead, they can decrease conviction rates, either through increased corruption or through a reluctance of jurors to impose such penalties. Andreoni (1991) shows that the latter mechanism leads to a principle of proportionality of the punishment and the crime.

Police crackdowns, i.e. the concentration of enforcement on a (random) subset of the population, are an ubiquitous feature of real world enforcement. Kleiman (2009) and Eeckhout et al. (2010) argue that crackdowns can be explained as an optimal response to congestion in enforcement.

Since any enforcement agency has limited funds, congestion is an important practical problem (Kleiman, 2009). With limited resources it may be impossible for authorities to fully implement higher detection rates over the whole population.⁸ If society is in a high crime equilibrium, such enforcement levels may simply be too low to 'tip' crime levels into a new equilibrium, and thus have little effect on the crime rate (Ferrer, 2010).

Kleiman (2009:52) illustrates by means of a simple example how crackdowns may raise the effectiveness of policy. Suppose there are two potential criminals who will find it optimal to commit a crime if and only if the probability of arrest is smaller than $2/3$. There is a sole police officer who can only lock up one person, and randomizes his arrests among offenders. This is an archetypical case of 'enforcement swamping' in which there are two equilibria: either no one commits a crime, in which case anyone who deviated from the equilibrium would be caught with probability one. In the second equilibrium both people commit a crime and the probability of being jailed is $1/2$. In the latter case, the police officer can reduce the crime rate from two to zero by committing in advance to give priority to the arrest of one of the two potential offenders. The person who is targeted will not offend because his conditional probability of arrest given offense is one. The second person, knowing this, knows that her probability of arrest given offense is now also one, so she also complies with the law.

This logic can be generalized to a larger community. If a community is in a high crime equilibrium and the regulator has limited resources, it may not be possible to 'tip' this equilibrium by spreading enforcement resources thinly over the population. Instead the regulator may concentrate enforcement on a small group. Once the people in this group have learned that they are being subjected to increased control, they will diminish their criminal activity. Enforcement can then be focused on the next group of offenders, following

a strategy that Kleiman calls ‘dynamic concentration.’ Note that the first group of offenders still has ‘priority’ and faces a high level of deterrence. Knowing this, they will offend less and therefore free up resources for raising enforcement on a new group of offenders. Proceeding in this manner will eventually result in fewer arrests and less crime.⁹ Kleiman (2009) shows several case studies in which this strategy has yielded good results. Sherman (1990), Braga and Bond (2008) and Eeckhout et al. (2010) provide empirical evidence for the success of concentrated police efforts.

This theory also explains why crackdowns are often announced in advance. The primary aim is not to catch as many offenders as possible, or to raise the subjective assessment of agents of the arrest rate above what it really is, although this may help reduce crime as well. Rather, it is to deter sufficiently many people to cause a snowball effect and tip the system into a new, stable equilibrium.

The mechanism works if the targets of crackdowns are random subsets of the population.¹⁰ However, if one puts more structure on the patterns of complementarities in the population, one can refine this strategy. For example, if crimes are committed sequentially, enforcement should concentrate on the first offender. In Kleiman’s (2009:55) words, a lone Texas ranger can stop a mob with a single bullet if he can credibly announce that he will shoot the first person who passes through the door. Targeting the key player in a criminal network (as explained in Section 3.1) is another way to optimize the effect of crackdowns.

In short, a feedback effect from crime to enforcement may induce similar multiplier effects as those arising from peer interactions and can rationalize the use of crackdowns.

3.4. ENDOGENOUS PREFERENCES

“It is hard to imagine a preference not shaped in part by legal arrangements.”

~Cass R. Sunstein (1986:1146)

Naturally, the costs and benefits of criminal activity depend on the values that individuals entertain, such as honesty and respect for others. Individual values are the result of processes of education, socialization and imitation. As the quote by Sunstein suggests, these processes are unlikely to be independent from the existence of formal enforcement institutions. Several law scholars argue that large areas of law should be understood as preference shaping policies rather than as deterrent measures (Dau-Schmidt, 1990; Meares et al., 2004).

Formal models of the effect of institutions on preferences have only slowly gained popularity in economics (although, see Fehr and Hoff, 2011). There is a small literature on the long-term effects of deterrent institutions on preferences, mostly using techniques of evolutionary game theory. Here, the term ‘evolutionary’ does not refer to a biological process, since this could take place only over a timespan in which institutions cannot reasonably be held constant. Rather, it refers to a process of cultural evolution, where preferences spread by processes of imitation and education.

Papers in this literature investigate a bilateral interaction between two individuals. These individuals are randomly drawn from a population consisting of a mix of selfish types, and types with traits favorable to cooperation, such as the capacity to feel remorse or guilt, or to value esteem from others. The crucial assumption is that types with higher payoffs in bilateral interactions are more likely to ‘survive’ or spread in the population. When the game is played infinitely often, one can determine the long-run equilibrium fraction of these types from the (material) payoffs of the interaction. Institutions that penalize criminal or anti-social behavior in one-shot interactions can thus be evaluated by their impact on the long-run population shares of both selfish and cooperative types.¹¹

3.4.1. *Endogenous Preferences and Law Enforcement*

Intuitively one would expect that formal sanctioning institutions will lower the payoffs of selfish types, and therefore lead to a larger long-run share of good types in the population. This is the case in Huck (1998). In his model, one party in a bilateral exchange is in the position to cheat on the other party, who can observe cheating at a cost. Detection of cheating leads to a legal penalty with some probability. In a static setting where preferences are fixed, higher penalties reduce cheating, i.e. the standard deterrence result holds. In a dynamic setting, penalties on cheating favor cooperative individuals, who are more likely to comply. Thus, cooperators can survive if sanctions are high enough. This in turn causes the optimal sanctions to fall in the long run.

Paradoxically, formal sanctions on cheating could also favor cheaters in the long run. Suppose that the legal system lowers the cost of cooperating with a cheater. This could be because the legal system makes cheaters compensate the other party if they are detected (Bohnet et al., 2001), or simply because it subsidizes cooperation (Bar-Gill and Fershtman, 2005). This will lead people to be less careful and trust (suspected) cheaters more, which increases the latter’s opportunities to cheat. If the penalties for cheaters are not too high, then the introduction of a legal system can make cheaters better off than honest types, and therefore increase their share in the population.

This argument relies on the strong assumption that types are observable, at least with some probability. Güth and Ockenfels (2005) show that when this assumption is dropped, legal institutions that punish non-cooperation become central to the evolution of cooperative preferences. Obviously, the reason is that cooperation can no longer be conditioned on type, and so private punishment of cheaters is impossible. As a consequence, cheaters will always be at least as well off as non-cheaters.

Tabellini (2008) provides a model that does not rely on observability of types, and adds a more explicit process for the evolution of moral values. He models a continuum of agents distributed uniformly on a circle, who play a one-shot prisoner's dilemma with a randomly matched partner. There are agents whose values dictate that they cooperate only with locals ('limited morality') and those who cooperate also with more distant partners ('generalized morality'). Agents decide whether to exert costly effort to transmit generalized morality to their children. The author shows that the effect of enforcement of cooperation on the transmission of values depends on the distance between the partners. Enforcement in local interactions increases the range of cooperation for those with local morality. This decreases the need for good parents to teach generalized morality to their children, since the children are likely to cooperate even without those values. By contrast, external enforcement in long-distance interactions implies that players with generalized morality will cooperate over a longer range. This raises the return to raising a 'good kid,' since good behavior is less likely to be exploited. Thus, local (or community) enforcement substitutes for moral values, whereas external enforcement complements it. The effect of better enforcement of cooperation in all kinds of interactions is ambiguous. The author also investigates the effect of values on enforcement, and shows that weak (local) values may lead to weak enforcement mechanisms, thus creating an institutional trap.

Although these results are interesting, and the literature is expanding, empirical evidence that may refine these models is scarce. Processes of cultural transmission play out over a large timespan and identifying causality is difficult. A suggestive study is Lappi-Seppälä (2001), which describes the remarkable change in the philosophy of the Finnish penal regime during the last 40 years. Spurred by prison overcrowding, the Finnish changed from a system that was based predominantly on repression to one that emphasizes moral education practiced at schools and other institutions. This was accompanied by a substantial reduction in penalties for many crimes in the 1970's. In contrast to the predictions of the deterrence hypothesis, crime

rates in Finland have not deviated from those in other Scandinavian countries. Given that law scholars stress the importance of the law on preferences in the long run (Dau-Schmidt, 1990), this area should definitely see more development.

4. CONCLUSION

Given the dynamics of law enforcement policies in the last decades, the stakes in the deterrence debate could hardly be higher. According to a recent report by the Pew Center (2008), one out of every 100 adults in the United States is in jail. This represents a more than 6-fold increase since the early 1970s, and is the result of an uninterrupted 36 year rise in the prison population. Trends of rising prison rates are observed in most OECD countries, although on a smaller scale of incarceration (OECD, 2007).

Prominent criminologists have attributed this trend towards tougher sentencing policies in the United States and Britain to an increased public confidence in the model of the rational criminal (Garland, 2001; Donohue, 2007; Kleiman, 2009). In the 1980s, the rational model of crime fit well with a political wave that championed individual responsibility. Starting with Wilson's *Thinking about Crime* (1975), this political current popularized policies to 'get tough' on crime.¹²

Indeed, the standard economic model emphasizes deterrence as the main policy instrument. Polinsky and Shavell's (2000) survey of the deterrence literature, concludes that in many cases the level of deterrence is "too low," and the authors suggest that

"Given the ample opportunities that exist for augmenting penalties, as well as the possible desirability of increasing enforcement effort, society should probably raise deterrence in many areas of enforcement."

~A. Mitchell Polinsky and Steven Shavell (2000:72)

The game theoretic approach to crime surveyed in this article shows that taking a rational choice perspective does not necessarily imply such a faith in more severe or more certain punishments. Once one moves beyond simple Prisoner's Dilemma-type of social interactions, the deterrence hypothesis provides little guidance to the effects of enforcement. Peer effects and social norms that stigmatize deviant behavior imply that in many situations 'mild law' may be sufficient to coordinate expectations and behavior. High penalties may lead to increased corruption, and lower detection rates. In markets for illegal goods, formal enforcement may operate like anti-trust, and

end up increasing supply and lowering prices. On the other hand, crackdowns, random episodic increases in monitoring effort, may be instrumental to escape from a high crime equilibrium. Signaling motives for crime can lead to subtle substitution effects, and may induce a 'double dividend' of deterrence.

Even though the research field is still young, this review shows that rational choice is a more versatile tool than many of its opponents have given it credit for. Game theory can provide formal backing for the insights from the criminology literature, and provide new analytical distinctions. At the same time, there are many important issues that game and rational choice theorists are only beginning to address. For example, due to their preoccupation with deterrence, rational choice theorists have largely ignored the effects of other policy instruments, such as education or reintegration programs. Another example is the issue of legitimacy. There is ample evidence that the effectiveness of laws and their enforcement depends crucially on the perceived legitimacy of the authorities. This implies a shift in attention from command and control policies to participatory procedures that induce voluntary compliance (Tyler, 2008).

It is the hope of the author that this article will help researchers working on crime in different fields to integrate, share and extend their insights.

Endnotes

* I thank Roberto Galbiati, Robert Dur, Christian Traxler, the editor and several anonymous referees for useful comments. Email: vdweele@econ.uni-frankfurt.de. Address: Department of Economics, Goethe University, Frankfurt am Main, Grüneburgplatz 1, D-60323 Frankfurt am Main, Germany.

1. McCarthy (2002) provides a very informative discussion of the relation between crime and game theory, but does not focus on policy implications. McAdams and Rasmusen (2007) provide a theoretical treatment on the role of social norms within law and economics.
2. However, even in a 'clean' laboratory setting the results may not be so straightforward. A similar experiment by Schildberg-Hörisch and Strassmeier (2011) shows that when penalties and probabilities are very small, they may actually *increase* unwanted behavior.
3. Some authors have written about the connection between the concept of Nash equilibrium and 'social norms' (McAdams and Rasmusen, 2007). There is also a literature on the regulation of norms (Lessig, 1995) and 'norm entrepreneurs' (Sunstein, 1996). There has been some formal attention to these ideas in economics (Kübler, 2001), but the subject warrants more attention. Festre (2010) has surveyed the economic literature on the interactions between social norms and incentives.
4. In coordination games, the optimal action is for players to behave in the same way as

others. A prime example of a pure coordination game is the decision on which side of the road to drive: left or right. No choice has an intrinsic advantage, what matters is that everyone would like to conform to what others are doing. In the parlance of game theory: driving on the right is a *best response* to others driving on the right. Coordination games arise when there are complementarities in behavior: if you drive on the right, my payoffs from driving on the right increase relative to the payoffs of driving on the left.

5. A different source of complementarities which can similarly result in multiple equilibria is the impact of the crime rate on the returns to legal activity. If crime and corruption are high, the benefits of legal activity diminish and crime becomes relatively more attractive, creating a vicious cycle. This type of reasoning can be incorporated into the standard model by assuming that the outside option depends on the crime decisions of others $\bar{U}_j = \bar{U}_j(n)$, where $\bar{U}_j' < 0$. Models in this spirit include Rasmusen (1996), who shows how high crime rates may depress wages in the legal sector, and Murphy et al. (1993), who show how corruption and rent-seeking may depress the relative returns to productive activities.
6. Signaling models typically use the concept of a perfect Bayesian Nash equilibrium. In this framework, beliefs about the other's type are formed by applying Bayes' rule. Upon observing a certain action, the inferred type of the agent is a weighted average of all types that commit that particular action in equilibrium, where the weights are determined by the prior belief. Equilibria in which different types distinguish themselves by taking different actions are known as 'separating equilibria.' Equilibria in which all types take the same action and no information is transmitted, are known as 'pooling equilibria.'
7. The models reviewed actually use some reduced form (1), which does not distinguish between the severity and certainty of incentives.
8. In fact, actual conviction rates are rather low. Robinson and Darley (2004) compute on the basis of data from the U.S. Justice Department that the average probability of being sentenced for a criminal offense that has been committed is 1.3%, although it is much higher for serious offenses. Andreoni et al. (1998) reports that in 1995, 1.7% of all U.S. taxpayers were audited. Of the people whose audit was reassessed, 4.1% paid a fine.
9. The precise source of complementarities matters here. Dynamic concentration works if the constraint of the authorities is capacity in jail cells. Lower offenders in the first group will free up capacity that can be used to increase deterrence in both groups. However, there may be a constraint on resources for monitoring as well. In this case, lower offense rates by one group do not allow the regulator to shift monitoring levels to a second group without a subsequent rise in crime in the first group. However, if there are local complementarities stemming from norms or peer effects, the first group may now be permanently tipped into a low-crime equilibrium, which will remain stable even if monitoring is switched to the second group.
10. Eeckhout et al. (2010) derive more formal conditions for this mechanism to work. Denote the deterrence level by d and the crime level by $c(d)$. Eeckhout et al. (2010) show that if $c(d)$ is concave on a subset of its domain, law enforcement agencies may be able to lower the crime rate by using random crackdowns. To see this, suppose the authorities spread their limited resources evenly and monitor everyone at the same level,

resulting in deterrence level \bar{d} . In a crackdown, the authorities can raise the deterrence rate to $d_h > \bar{d}$ for a fraction μ of the population, and lower it to $d_l < \bar{d}$ for a fraction $1 - \mu$. The resulting crime rate is $\mu c(d_h) + (1 - \mu)c(d_l)$ which is lower than $c(\bar{d})$ if $c(d)$ is concave at \bar{d} .

11. This approach in which evolution operates on preferences is called the ‘indirect evolutionary approach.’ In an alternative, more standard approach, individuals are assumed to simply play a given strategy. In this case, evolution impacts directly on the relative frequency of individuals who play different strategies.
12. Empirical study confirms that such policies are mostly responsible for the explosion in the prison population. Blumstein and Beck (1999) investigated the near-tripling of the U.S. prison population during the period 1980-96 and conclude that changes in crime explained only 12% of the rise. Changes in sentencing policy on the other hand accounted for 88% of the increase.

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