Breaking the law when others do: A model of law enforcement with neighborhood externalities

Rosa Ferrer*
Department of Economics
Vanderbilt University

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Abstract

A standard assumption in the economics of law enforcement is that the probability of a violator being punished depends only on the resources devoted to enforcement. However, it is often true that the productivity of enforcement resources decreases with the number of violators. In this paper, an individual who violates the law provides a positive externality for other offenders because the probability of being punished decreases with the number of individuals violating the law. This externality explains the existence of correlation between individuals' decisions to break a law. The model evaluates the implications when determining the socially optimal enforcement expenditure, focusing specifically on the case of neighborhood crime. In particular, using a parametrized functional form, I show that neighborhood externalities will enhance or impede enforcement, depending on the crime rate.

1 Introduction

Socioeconomic conditions of poverty, inequality, education and unemployment do not fully explain the differences in crime rates across locations. Such differences in crime rates remain an open question in the law enforcement literature. This paper studies an alternative explanation that regards the interdependence of individuals' decision to break the law as an important source of the variance in rates of compliance. In contrast to previous work[1] that focuses on behavioral assumptions, this paper demonstrates that such interdependence can also arise from conventional assumptions of rational utility maximizing behavior.

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[1] See for instance Glaeser et al. (1996) and Sah (1991), which are discussed below.

Standard theories of the economics of law enforcement assume that the likelihood that a violator is punished depends only on the level of resources that are devoted to enforcement. However, it is often true that the productivity[2] of enforcement resources depends upon the number of people that engage in the illegal activity. This paper considers two positive externalities among offenders that may explain neighborhood differentiation. By affecting the productivity of enforcement resources, these externalities create interdependence between individuals' decision to violate the law.

As shown below, these externalities must be accounted for in evaluating individual payoffs from violating the law because they affect considerably optimal enforcement policy. One externality is caused by congestion in enforcement. It creates a positive externality among offenders because (for a fixed level of enforcement resources) an increase in the number of violators leads to a lower amount of enforcement resources per violator, yielding a lower likelihood that a violator is punished. This case arises when enforcement resources are needed for punishment and detection activities, rather than for detection alone. For example, if there is only one tow-truck in the neighborhood, an increase in the number of cars that are illegally-parked reduces the probability that a given car is towed since there are fewer enforcement resources (tow-trucks) per violator. In the model the number of violators is determined in equilibrium; hence, the magnitude of this externality is generated endogenously.

The second externality is caused by the community's degree of involvement in enforcement activities. The role of citizens in the enforcement process is important since they may alert authorities, provide evidence, and denounce offenders. Thus, the productivity of enforcement resources increases in the community's degree of involvement. First, I consider the degree of involvement as an exogenous characteristic of the neighborhood, this allows me to discuss the effect of policies that may change this degree of involvement. Second, Section 4.4 extends the results to the case of neighborhood involvement being a decreasing function of the non-compliance rate (and thus, being determined endogenously), as it is the case when non-compliers may retaliate against neighbors who provide information to police.

The probability of punishing a violator is determined endogenously depending on the enforcement resources and on individuals' decisions in equilibrium. A functional form for this probability permits me to evaluate the effects of the externalities. The results show that the externalities have crucial effects on the optimal law enforcement policy. First, they create multiple equilibria; thus, more than one compliance level may result for a given amount of enforcement resources. To find the optimal enforcement policy, the enforcement agency must be able to identify which of the equilbria will be selected. As I argue, risk dominance seems the most suitable selection criterion in this framework. After one equilibrium has been selected, the effects of the externalities remain. In particular, they may cause enforcement to be too costly, which helps explain how some neighborhoods become "no-go" zones for police.

[2] The outcome of the enforcement process is the likelihood that a violator is punished. Thus, the productivity of the enforcement resources is measured in terms of that likelihood, or consequently, in terms of the resulting crime rate.

In such cases, an alternative is to enforce the law through community policing. The paper formally models how differences in the involvement in enforcement activities between two otherwise identical neighborhoods may create divergences in crime rates. Other alternatives are policies that make apprehension and punishment depend less on the number of violators. Examples of these types of policies for traffic violations are demerit point systems and electronic citation programs.

The model is presented in Section 2. As a benchmark, Section 3 provides the results when there are no externalities. Section 4 solves the model with externalities. Section 5 considers as an example the case where congestion is the only externality. Section 6 extends the model to a framework with heterogeneous individuals. Finally, Section 7 concludes.

Related literature

In an empirical study on crime, Ehrlich (1973) showed that the probability of apprehending and convicting felons is not only positively related to the level of current police resources, but also negatively related to the crime rate. He argued that this is the case "because more offenders must then be apprehended, charged and tried in court in order to achieve a given level of P [probability of the sanction]." Surprisingly however, much of the literature on the economics of law enforcement has ignored this evidence by assuming that the probability of the sanction is determined exclusively by the amount of enforcement resources.

One notable exception is Freeman, Grogger and Sonstelie (1996). In a model with two neighborhoods, they consider how congestion may cause criminals to create an externality for each other: when the number of thieves increases, the probability of being arrested decreases. They show that multiple equilibria arise as a consequence of this externality. One possible equilibrium is that for a given homogenous police effort, crime may concentrate in one neighborhood instead of spreading to the other. My work differs from theirs in several ways. First, rather than take enforcement resources as exogenous, I take these enforcement resources as strategically determined by the enforcement agency, which is an active agent of the model. Second, I study further effects of the externalities by introducing criteria of equilibrium selection. Third, their analysis focuses on the externality caused by congestion of enforcement resources while I consider also the externality that arises through the involvement of the neighborhood in enforcement activities.

Using a behavioral approach, some authors have studied how individuals' decisions to violate the law may be interdependent. In a model where individuals are not able to observe the true probability of being punished, Sah (1991) models factors that affect individuals' "perception" of that probability. Assuming that past experiences influence individuals' perception, an individual chooses whether to be a criminal depending on her own and her acquaintances' past experiences. The model considers the crime participation rate as a "negative input" of the criminal apprehension system. Thus, an individual's propensity to commit crime is increasing in past crime rates because the higher the number of criminals in the past, the less likely that she or her cohorts were punished. Glaeser, Sacerdote and Scheinkman (1996) consider a model in which a fraction of the population simply imitates what their neighbors do. The variance of the crime rate is shown to be negatively related to the number of individuals not affected by their neighbor's choice (i.e., negatively related to the number of individuals that maximize their utility instead of simply imitating). That is, they model how the variance of the crime rate may be increasing in the degree of social interaction in a neighborhood (i.e., imitation in this model). In the empirical part of their study they show that the crime rate variance that is not explained by differences in economic and social local conditions[3] can be explained by the correlation of agents' decisions. Consistent with this result, I provide a model of how individuals' decisions may be interdependent in a framework where all individuals are utility maximizers.

Two other results from Glaeser et al. (1996) are important for my analysis. They argue that, although crime models with multiple equilibria generate a higher variance in the crime rate than do other models, the existence of multiple equilibria is not enough to explain the high variance in crime rates. In their data, they show that differences in crime rate across communities (once they control for socioeconomic conditions) cannot be explained by crime rates clustering around a few possible equilibria. The externalities I study in the paper generate multiple equilibria but, more importantly, their effects go beyond this result. After adopting a criterion of equilibrium selection, I show that how sensitive the enforcement technology is to the externalities is crucial in determining the optimal enforcement policy. In addition, although Glaeser et al. (1996) do not find congestion in enforcement resources as a significant cause of crime-rate variance, it might be due to the proxy variable used for crime rates. To assess the effect of congestion they study the correlation between arrest rates and crime rates. The rate of arrests might not provide enough information about the ratio of criminals that are effectively punished. Using the number of arrests leaves out the possibility of congestion during the investigation and conviction process.[4] As I argue throughout the paper, congestion arises because as the number of violators increases, enforcement resources per violator decrease. Hence, it seems more appropriate to study the correlation between guilty verdicts and crime, rather than between the number of arrests and crime.

Previous literature has studied other causes of multiple equilibria in illegal behavior. Schrag and Scotchmer (1997) consider the case of crime opportunities available to many potential criminals. If there exists a positive probability of punishing an innocent for a crime they did not commit, the authors show that it might actually be rational for an individual to commit a crime only when the crime rate is high. This is the case because, for high enough crime rates, the individual is likely to be punished regardless of being innocent or guilty. For a fixed enforcement budget, multiple equilibria are obtained, each with a different crime rate. Because of multiple equilibria,

[3] Unemployment rate, high school dropout rate, property taxes per capita, police per capita, regional dummy variable, persons over age of 25, etc.

[4] Furthermore, Glaeser et al. (1996) do not find correlation between arrest rates and crime rates in New York precints; however, as discussed in Levitt (1998), several other studies have found a negative relationship between arrest rates and crime rates. Although this effect may be due to deterrence, the author concludes that "it is difficult to control for potential endogeneity of arrest rates." Therefore, it could be that higher crime rates negatively affect arrest rates due to congestion.

upon concluding that the crime rate cannot be predicted from the enforcement policy, they do not undertake an analysis of optimal law enforcement. Rasmusen (1996) constructs a model wherein employers have incomplete information about workers' criminal activity. He shows that the stigma of being convicted (reduction in the wage employers are willing to pay someone with a criminal record) is decreasing in the non-compliance rate. As a consequence multiple equilibria arise because the lower the stigma, the higher the "attractiveness" of becoming a criminal.

Bar-Gill and Harel (2001) discuss in detail several ways in which the crime rate might feed back into the expected sanction. They argue that the expected sanction could be a decreasing function of the crime rate, either because of resource congestion or due to learning from fellow criminals; this is also the approach taken in this paper. They also note the possibility of multiple equilibria, but they do not characterize the full set of equilibria nor select among them. In addition to characterizing and selecting among equilibria, my analysis also differs from Bar-Gill and Harel in that I use a parametrized functional form for the enforcement technology that allows me to parametrize how sensitive the technology is to the externalities. I find that, for a given crime rate and level of investment in enforcement, the externality among criminals can either enhance or impede enforcement, depending on the crime rate. Thus, my model allows for the net effect on enforcement of the externalities to be determined in equilibrium.

In what follows I will assume that the fine is fixed exogenously, so that the level of enforcement resources is the sole decision variable of the enforcement agency.[5] This is reasonable because the fine is set by a legislative body (or perhaps by judicial precedent) with broad jurisdiction, while the level of enforcement resources is chosen at a more local level and through a shorter-term process. Notice that although the total number of enforcement resources might be decided at a supralocal level (e.g., decided by the state), urban and local authorities may decide how those resources are distributed across neighborhoods or communities whithin their area.

[5] According to Becker's (1968) seminal study on crime and punishment (see also Stigler, 1970), optimal enforcement involves the highest possible fine and the lowest possible apprehension probability that are consistent with the desired expected sanction. Others have argued that less-than-maximal fines may be optimal when more complicated incentives are involved. Stigler (1970) and Mookherjee (1994) invoke the need for marginal deterrence; Polinsky and Shavell (1979, 2000) and Block and Sidak (1980) include costs associated with risk-bearing; and Malik (1990) includes avoidance and/or collection costs that increase with the magnitude of the fine.

2 The Model

The basic structure of the model is similar to Polinsky and Shavell (1979). There is an enforcement agency that aims at maximizing social welfare and a continuum of risk neutral utility-maximizing individuals.

2.1 The individuals

There is a continuum of risk neutral individuals of measure 1, which represents the population of potential offenders.[6] Individuals are assumed to be homogenous in Section 4 and 5. This assumption is relaxed in Section 6. Each of the individuals may either comply with the law, denoted as {C}, which yields zero payoff, or not comply with the law, denoted as {NC}, which implies a benefit, b, but also a possible fine, $f > 0$. The fine is imposed with a probability P that is determined endogenously as explained below. The benefit is net of any cost (excluding the fine) associated with not complying (e.g., moral cost). Both b and f are exogenous to the model. I assume that $b < f$, that is, there is always a high enough probability, $P > b/f$, that deters individuals from violating the law.

The choice of a single individual has a negligible impact on the society; therefore it has no effect on P. Thus, an individual commits an offense if $P < b/f$, but not if $P > b/f$, and will be indifferent otherwise. Therefore, the proportion of individuals not complying is given by a function of the probability of the sanction, $\mu = R(P)$ where:

$$R(P) \begin{cases} = 1 \text{ if } P < b/f \\ \in [0,1] \text{ if } P = b/f \\ = 0 \text{ if } P > b/f \end{cases} . \tag{1}$$

2.2 The enforcement agency

The enforcement agency maximizes social welfare by choosing the amount of enforcement resources $c \in \mathbb{R}^+$. The sanction associated with non-compliance, $f > 0$, is exogenous for reasons explained in the Introduction. Therefore the decision variable of the agency is the enforcement resources, c, which includes all the needed expenses in detecting, prosecuting and fining, so as to make the fine truly imposed. Hence, c describes the public resources that are used for enforcement activities.

Social welfare is measured by considering that first, non-compliance should be deterred because each individual not complying with the law generates a harm, h, to the community and that second, (for a fixed level of aggregate harm) the lower the expenditure on enforcement the better off society is. For a given non-compliance rate, denoted above as μ, the harm generated is $h \cdot \mu$. In addition, the fines are assumed to be mere transfers of money and hence the revenue obtained from them

[6] Although every individual could be considered as a potential criminal, some individuals are deterred by very small levels of enforcement resources due, for instance, to moral costs. Thus, I am excluding them from the analysis.

does not affect the choice of the agency. Therefore, the enforcement policy that maximizes social welfare is given by:

$$c_{opt} = argmax_c \, SW(c) = argmax_c \quad - h \cdot \mu^*(c) \ - c, \qquad (2)$$

where $\mu^*(c)$ is the equilibrium non-compliance rate among individuals who are contemplating crime.

The timing of the decisions of the agency and of the individuals is:

Stage 1: The agency decides how much to spend on enforcement, c.

Stage 2: Individuals decide whether or not to comply with the law.

The agency anticipates the behavior of the individuals since it has perfect information about the individuals' payoffs.

2.3 The enforcement technology

The enforcement technology consists of the process that determines the probability of a law-violator being sanctioned, P, given the enforcement resources and the non-compliance rate. Therefore, it assembles all the activities related to detection, apprehension and punishment. In principle, the enforcement technology describes how effective the enforcement agency is in punishing violators. However, violators may engage in avoidance activities (like sharing information on how to avoid being punished) that should also be taken into account when modeling the enforcement technology.

The probability of the sanction, P, is not a (direct) decision variable of the agency and it will be determined endogenously. The enforcement technology is given by the function p, defined over $(c, \mu) \in \mathbb{R}^+ \times [0, 1]$ where the function p is increasing in c and decreasing in μ. Given the enforcement resources, c, and a non-compliance rate, μ, the probability of being sanctioned is given by $P = p(c, \mu)$.

Because of the positive externality[7] among offenders, the enforcement technology is such that the higher the non-compliance rate, the lower the probability of the sanction (i.e., $p_\mu < 0$). This positive externality among offenders arises due to congestion in enforcement resources. Also, it could arise when offenders share information or techniques on how to avoid detection and punishment. Since the non-compliance rate is determined in equilibrium, the magnitude of this externality is endogenous in the model. The function $p(c, \mu)$ also depends on several exogenous parameters which do not appear in the notation. One important parameter reflects a second externality that may arise in communities, which has to do with the involvement of its members in enforcement. The information that members of the community have plays an important role in the enforcement process since they may alert authorities, provide evidence, and denounce offenders. That is, the

[7] In this paper, the externality among offenders is always positive. In contrast, Calvó-Armengol and Zenou (2004) consider a model of social networks in which there is a negative externality among delinquents because they compete in criminal activities. Competition in criminal activities commonly arises in environments of organized crime, however, in other illegal activities there is usually no (significant) booty to fight for. Bar-Gill and Harel (2001) also discuss the possibility of a negative externality among offenders. While this negative externality is certainly possible, it would predict a negative correlation in criminal behavior, which seems to be at odds with the available evidence.

information has an effect on the productivity of enforcement.[8] The involvement of a neighborhood in enforcement is measured by η and first I consider it as exogenously given for each neighborhood. Section 4.4 extends the results to the case where η is decreasing in μ that is, to the case where the neighbours' involvement is decreasing in the non-compliance rate. When $\eta = 0$ there is no involvement, hence the enforcement authority is not able to benefit from the information neighbors have. The higher is η, the more able is the authority to benefit from this information, that is, $p_\eta > 0$. Diverse factors may affect the value of this parameter. For instance, language differences between the police and the neighbors may decrease the level of involvement.

In order to have closed-form solutions for the optimal level of enforcement resources, a particular functional form for p is employed. A second advantage of assuming a specific functional form is that it allows me to measure the results in terms of the sensitivity of the technology to the externalities. A specific functional form is a restrictive assumption; however, the form assumed represents a large family of functions and satisfies desirable properties.

The probability of the sanction is given by the following function[9] defined over the enforcement resources and the non-compliance rate, $p : \mathbb{R}^+ \times [0,1] \rightarrow [0,1]$:

$$P = p(c, \mu) = kc^\alpha/(1 + \mu - \eta)^\chi \tag{3}$$

where p can be considered as a production function that is increasing in c but decreasing in μ (i.e., $p_c > 0$ and $p_\mu < 0$). The parameters of this production function are $k > 0$, which expresses additional factors that may affect the enforcement technology such as specific characteristics of the type of illegal behavior; and $\alpha \in (0,1)$, which implies that there are decreasing returns with respect to the level of enforcement resources (i.e., $p_{cc} < 0$). Also, $1+\mu-\eta$ measures the overall neighborhood effect, where $\eta \in [0,1)$ measures the community's involvement in policing activities, and μ is the non-compliance rate in the neighborhood. While the externality created by η is an exogenous characteristic of the neighborhood, the externality created by μ is determined endogenously in the model.

Finally, $\chi \in (0,1)$ measures how sensitive the technology is to the externalities. Notice that $-\chi$ is the elasticity of p with respect to the overall neighborhood effect $1 + \mu - \eta$. When $\chi = 0$, then μ and η have no effect on the probability of the sanction. In such a case, P depends only on the level of enforcement resources. This case will be used as a benchmark. Furthermore, if $\eta > \mu$ the net effect of the externalities is positive for enforcement since then $p_\chi > 0$. Alternatively, the externalities have a negative net effect when $\eta < \mu$ because then $p_\chi < 0$. In Section 5, I study as an example the case in which congestion is the only externality; that is, the case where $\eta = 0$.

[8] Sampson (2004) finds evidence that "exposes the centrality of citizens as the engine of crime control."

[9] I will make the necessary parametric assumptions in order to ensure that $P \in [0,1]$. In particular, I impose that $P = 1$ when the level of enforcement resources is $c > ((1 + \mu - \eta)^\chi/k)^{1/\alpha}$. Footnote (16) discusses the implications when modelling the equilibrium selection.

2.4 Equilibrium condition for the individuals' behavior

Because of the positive externality among offenders, each individual cares about the rest of the individuals' decisions with respect to compliance. Therefore an individuals' equilibrium is only reached when, given the non-compliance rate, no individual is willing to change her decision as to whether to comply or not.

Definition 1 *: Given the enforcement resources, c, the non-compliance rate $\mu^* \in [0,1]$ is an* ***equilibrium for the individuals' behavior*** *if it satisfies the following condition: $\mu^* = R(p(\mu^*, c))$. That is, the non-compliance rate μ^* is consistent with the probability of the sanction resulting from c enforcement resources and a non-compliance rate μ^*.*

The equilibrium condition for individuals' behavior can be rewritten as a function of the enforcement resources, c, through the following function $\mu^* : [0,1] \to [0,1]$:

$$\mu^*(c) = \begin{cases} 0 \text{ if } p(0,c) > b/f \\ \hat{\mu} \text{ if } p(\hat{\mu}, c) = b/f \\ 1 \text{ if } p(1,c) < b/f \end{cases}, \tag{4}$$

where given c, $\hat{\mu}$ satisfies $\hat{\mu}(c) = (fkc^\alpha/b)^{1/\chi} - 1 + \eta$ for $\chi > 0$ and $\hat{\mu}(c) = [0,1]$ for $\chi = 0$. Notice that $\hat{\mu}(c)$ belongs to the interval $[0,1]$ for all c.

3 The benchmark: optimal policy in the absence of externalities

The analysis excluding the externalities (i.e., when imposing $\chi = 0$) provides the results obtained in the standard law enforcement literature. For this reason, the results of this section are used as a benchmark. Notice that when $\chi = 0$, p becomes a one-to-one, increasing and concave function of the enforcement resources, c, alone. For any given c, $p(c)$ is uniquely determined, independent of the rate of non-compliance:

$$P = p(c) = kc^\alpha \quad \text{for all } c \in \mathbb{R}^+. \tag{5}$$

Whenever $\chi = 0$, each individual complies or not with the law depending only on the enforcement resources, since other individuals' choices have no effect on her payoff function. Notice that there is a level of enforcement resources that constitutes a threshold for the individuals.

Definition 2 *Let $\tilde{c} \in \mathbb{R}^+$ be such that $p(\tilde{c}) = \frac{b}{f}$ is satisfied. I refer to $\tilde{c}$ as the threshold level of enforcement resources in the absence of the externalities.*

Considering the functional form of p, notice that $\tilde{c} = (b/fk)^{1/\alpha}$ and $p(\tilde{c}) \leq 1$. Now, the non-compliance rate in equilibrium can be rewritten as a function of c. Therefore, for any $c \in \mathbb{R}^+$, the equilibrium of the individuals' behavior is given by:

$$\mu^*(c)\begin{cases} = 1 \text{ if } c < \tilde{c} \\ \in [0,1] \text{ if } c = \tilde{c} \\ = 0 \text{ if } c > \tilde{c} \end{cases}. \tag{6}$$

Therefore, the equilibrium of the individuals' behavior is unique for any given c, except for $c = \tilde{c}$.

The agency anticipates the behavior of the individuals and chooses the optimal policy according to it. Therefore, the optimal policy of the enforcement agency, $c_{opt} \in [0,1]$, is obtained by backwards induction:

$$c_{opt} = argmax_c \, SW(c) = argmax_c \quad -h \cdot \mu^*(c) \ - c, \tag{7}$$

Solving the maximization problem of the agency simply consists of evaluating the enforcement resources needed to avoid the harm produced by non-compliance. Therefore, computing the optimal policy just involves comparing the values of h and $\tilde{c}$. Whenever the harm produced by non-compliance is large enough the agency will enforce the law by spending $\tilde{c}$.

Proposition 1 *In the absence of the externalities, equilibrium enforcement and compliance can be characterized as follows*[10]*:*
i) If $\tilde{c} \geq h$ the optimal enforcement resources are zero, $c_{opt} = 0$, which yields a no-compliance equilibrium, $\mu^*_{opt} = 1$.
ii) If $\tilde{c} < h$ the optimal enforcement resources are the threshold, $c_{opt} = \tilde{c}$, which yields a full-compliance equilibrium, $\mu^*_{opt} = 0$.

Proof. The proof is straightforward. ■

Considering zero enforcement resources as optimal (as is the case in the model for certain parameter values) or having equilibrium rates with either full or no-compliance may seem unusual in real life. However, let me emphasize that μ measures the compliance rate among potential criminals. There may be many members of the community that do not behave illegally even when enforcement resources are very low (for instance because illegal behavior has strong moral costs for them) and thus are outside of my analysis. In any case, Section 6 extends the model to a framework where the potential offenders are heterogeneous.

4 Law enforcement under the externalities

As already discussed in subsection 2.3, the enforcement technology depends on its sensitivity to the externalities, χ, and on their net effect, $\mu - \eta$. Recall that $p_\chi < 0$ when $\mu > \eta$ and $p_\chi > 0$ when $\mu < \eta$. That is, the presence of externalities decreases the probability of sanction if the noncompliance rate exceeds the rate of community involvement, and increases the probability of sanction if the rate of community involvement exceeds the non-compliance rate.

[10] Two subtle issues arise with respect to Proposition 1; they are discussed in the Appendix.

4.1 The individuals' behavior

In contrast with the benchmark, whenever $\chi > 0$ the probability of the sanction depends also on the non-compliance rate of the community. Then the decision of an individual with respect to compliance depends on other individuals' choices. When the individual decides not to comply, her utility is given by $b - p(c, \mu) \cdot f$. Hence, an individual may decide to comply with the law when the non-compliance rate is low (which yields a larger value of $p(c, \mu)$) and not to comply when the non-compliance rate is high (because it yields a smaller value of $p(c, \mu)$).

Definition 3 *Let $\underline{c} \in \mathbb{R}^+$ be such that $p(\underline{c}, 0) = \frac{b}{f}$. I refer to $\underline{c}$ as the minimal enforcement resources needed to reach $P = b/f$.*

That is, $\underline{c}$ is the level of enforcement resources needed to make individuals indifferent between compliance and non-compliance when the rate of non-compliance is zero. For the functional form specified for p, $\underline{c} = (b(1-\eta)^{\chi}/fk)^{1/\alpha}$.

Definition 4 *Let $\bar{c} \in \mathbb{R}^+$ be such that $p(\bar{c}, 1) = \frac{b}{f}$. I refer to $\bar{c}$ as the maximal enforcement resources needed to reach $P = b/f$.*

That is, $\bar{c}$ is the level of enforcement resources needed to make individuals indifferent between compliance and non-compliance when the rate of non-compliance is 1. For the functional form specified for p, $\bar{c} = (b(2-\eta)^{\chi}/fk)^{1/\alpha}$.Thus, for $\eta \in [0, 1)$:

$$\underline{c} \leq \tilde{c} < \bar{c}. \tag{8}$$

Notice that if the agency is not able to benefit from the information of the neighbors (i.e., $\eta = 0$) then $\underline{c}$ coincides with $\tilde{c}$.

The equilibria for the individuals' behavior can be characterized in terms of $\underline{c}$ and $\bar{c}$ as shown in Figure 1. Notice that for $c < \underline{c}$ and for $c > \bar{c}$ the individuals' equilibria coincides with those of the benchmark case. First, for $c < \underline{c}$, no-compliance ($\mu^* = 1$) is the unique equilibrium possible, since by definition of $\underline{c}$, if $c < \underline{c}$ then $p(c, \mu) < \frac{b}{f}$ for all μ; hence it is optimal for the individuals to violate the law. Second, for $c \geq \bar{c}$, full-compliance ($\mu^* = 0$) is the unique equilibrium possible since by definition of $\bar{c}$, if $c \geq \underline{c}$ then $p(c, \mu) \geq \frac{b}{f}$ for all μ; hence it is optimal for all individuals to comply.

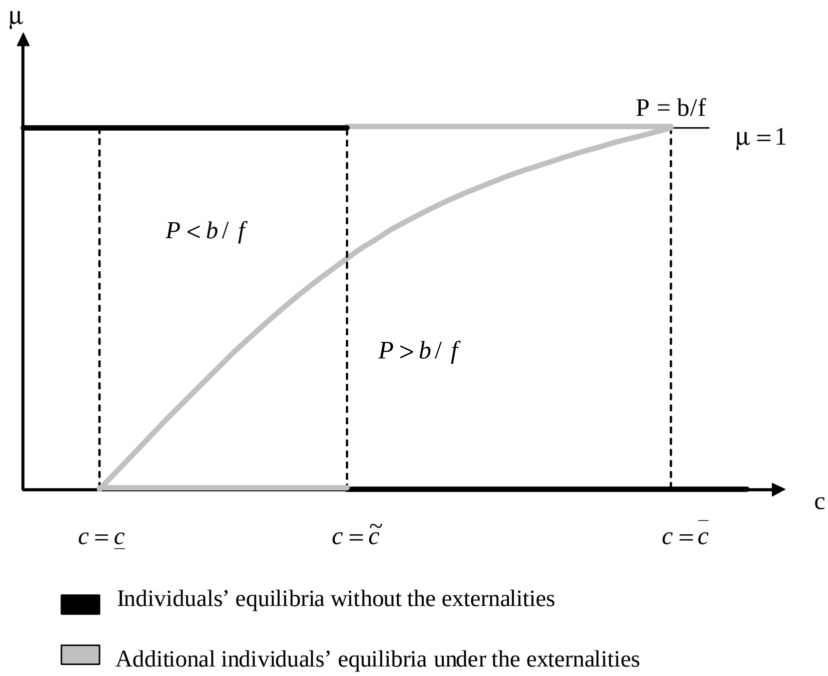

Figure 1: Equilibria of the individuals

However, because of the externalities there is an interval of enforcement resources for which individuals' equilibria differ from the benchmark. In particular, as shown in Figure 1, for this interval of resources there are multiple equilibria.[11]

Proposition 2 *For any level of enforcement resources* $c \in [\underline{c}, \bar{c}]$*:*
i) Independent of the technology's sensitivity to externalities (i.e., for any $\chi \geq 0$*) there exists a no-compliance equilibrium,* $\mu^* = 1$*, for* $c \leq \tilde{c}$ *and a full-compliance equilibrium,* $\mu^* = 0$*, for* $c \geq \tilde{c}$*.*
ii) If the technology is sensitive to the externalities (i.e., $\chi > 0$*), then in addition, there is a no-compliance equilibrium (*$\mu^* = 1$*) for* $c > \tilde{c}$*, a full-compliance equilibrium,* $\mu^* = 0$*, for* $c < \tilde{c}$ *and a partial-compliance equilibrium,* $\mu^* = \hat{\mu}(c) \in [0, 1]$*, for any* $c \in [\underline{c}, \bar{c}]$*.*
Furthermore, the length of the interval $[\underline{c}, \bar{c}]$ *is increasing in* χ*.*

Due to the presence of externalities, more than one equilibrium arises for a given amount of enforcement resources $c \in [\underline{c}, \bar{c}]$. Intuitively, because the net effect of the externalities on enforcement may be positive, some of the new equilibria that arise are good equilibria from the perspective of the enforcement agency. In particular, full-compliance equilibria can now be sustained for levels of enforcement resources below the threshold $\tilde{c}$.

Furthermore, a higher elasticity of the enforcement technology with respect to the overall neighborhood effect implies a larger range of enforcement resources for which there are multiple equilibria.

[11] In Figure 1, the level curve $p(c, \mu) = b/f$ is represented for $\chi < \alpha$, which makes it concave. For $\chi > \alpha$, we would have that the level curve $p(c, \mu) = b/f$ is convex. However, the analysis is equivalent.

This is because a larger χ results in a smaller $\underline{c}$ and a larger $\bar{c}$. Thus, there is more room for multiple equilibria the more sensitive the technology is to the externalities.

4.2 Equilibrium selection and policy implications

For any given c in the range $[\underline{c}, \bar{c}]$, the full compliance equilibrium is the socially desirable one; however, it may be that it is not the equilibrium selected by the individuals. This subsection discusses possible selection criteria for the individuals' behavior when there are multiple equilibria, that is, when $c \in [\underline{c}, \bar{c}]$. I will adopt risk dominance as it seems the most adequate criterion in this framework.

4.2.1 Equilibrium payoffs

At the no-compliance equilibrium, each individual attains a payoff:

$$b - p(c, \mu = 1) \cdot f > 0 \text{ for } c < \bar{c}. \tag{9}$$

Thus, it appears that the no-compliance equilibrium payoff dominates both the full compliance and the partial-compliance equilibria since the latter two yield a payoff of zero. However, determining the payoff-dominant equilibrium is more elaborate than this simple comparison. Notice that in the description of the model I have not considered how the harm caused by non-compliance, h, may affect the payoffs of the individuals. Since there is a continuum of individuals, each individual takes this harm as given. Therefore, the harm does not affect their decision-making processes and including it does not alter the optimal responses of the individuals; however, it does affect their payoffs.

To illustrate this argument, let v_i be the function that determines the specific harm[12] that illegal behavior causes to an individual i depending on the social harm, $h\mu$. Being at the no-compliance equilibrium makes an individual i worse off than being at either the full-compliance or the partial compliance equilibria if:

$$b - p(c, 1) \cdot f - v_i(h) < 0.$$

However, being worse off does not induce individual i to deviate from her equilibrium strategy. For instance, living in a neighborhood where illegal behavior is the rule might make individuals worse off, but it will not keep them from breaking the law when it is optimal. Therefore, introducing the harm caused by others' non compliance in the payoff function does not affect the best-response correspondences of the individuals, but it does affect how the multiple equilibria are ranked in terms of payoffs.

This problem is not new in game theory. Harsanyi and Selten (1988) argue that, for rational

[12] It is beyond the scope of this paper to study the ways in which illegal behavior may harm agents individually. Thus, I simply allow illegal behavior to affect individuals in the neighborhood differently, for instance it could depend on the type of illegal behavior or on the structure of the neighborhood.

individuals, transformations of the game that do not affect their best-response correspondences should not affect which equilibrium is considered as focal. Payoff dominance does not satisfy this requirement. In contrast, as explained by Harsanyi and Selten (1988) and by Myerson (1991), risk dominance is a solution concept that is invariant to changes in the agents' payoffs that do not affect their best-response correspondences. In the next subsection, I use risk dominance to predict the equilibrium that will be selected by the individuals.

There are also other reasons why risk dominance seems more adequate than payoff dominance in this model. First, recent experimental findings (Van Huyck et al (1990), Straub (1995) and Schmidt et al. (2003)) have shown the difficulty players have in coordinating to reach the payoff-dominant equilibrium, and also the important role of risk dominance in explaining individuals' behavior in coordination games. Second, since there is a continuum of individuals in the model, coordination on the payoff-dominant equilibrium seems even less likely. Finally, choosing not to comply for all $c \in [\underline{c}, \bar{c}]$ is a risky strategy since the individuals have uncertainty about what the rest of the individuals will choose. In particular, the higher is c, the higher is this strategic risk. The concept of risk-dominance accounts for how this uncertainty affects the behavior of the individuals.

4.2.2 Equilibrium selection

The concept of risk dominance[13] (Harsanyi and Selten (1988)) consists of individuals choosing the less risky equilibrium action, incorporating each individual's uncertainty about the strategy that the rest will end up choosing in equilibrium. Hence, under risk dominance each individual's strategy consists of the best response when assigning a positive probability to the possibility of other individuals choosing the non-equilibrium strategy (i.e., there is a risk that the rest of the individuals will choose to comply when the individual has chosen not to comply or vice versa[14]).

The risk-dominance selection concept is typically applied in the context of two player games, while in this context there is (formally) a continuum of players. However, the setup of the model allows us to easily interpret individuals' behavior as a game with two players and two strategies per player. Consider the decision process of an individual i by interpreting the model as a 2x2 game where all other players are represented by a "representative agent." Thus, individual i decides whether to comply or not, and his payoff depends on the strategy chosen by a representative agent that reflects the choice of the rest of the potential offenders. Because there is a continuum of individuals the contribution of individual i's choice to the payoff of the representative agent is negligible. As a consequence, the non-compliance rate is 0 whenever the representative individual decides to comply and 1 when she decides not to comply.

[13] For a recent application of risk dominance in a law and economics setting, see Spier (2002).

[14] I restrict attention to the full-compliance and no-compliance equilibria because these are the only types of equilibria that arise in the model with no externalities. Also, notice that the partial compliance equilibrium is unstable in the myopic adjustment sense. That is, a slight perturbation of μ away from $\hat{\mu}(c)$ leads to best response behavior that continues to move away from the initial partial compliance equilibrium.

PAYOFFS FOR INDIVIDUAL *i*		Representative individual	
		COMPLY	NOT COMPLY
Individual i	COMPLY	0	0
	NOT COMPLY	$b-\frac{kfc^{\alpha}}{(1-\eta)^{\chi}}$	$b-\frac{kfc^{\alpha}}{(2-\eta)^{\chi}}$

Table 1: Payoffs for individual *i* when η is exogenous

Payoffs for individual i are shown in Table 1. Risk dominance allows the individuals to select between the multiple equilibria that arise when $\chi > 0$ and $c \in [\underline{c}, \bar{c}]$. Given the enforcement resources, individuals choose the risk dominant strategy. As a consequence, the following equilibrium selection takes place.

Proposition 3 *There exists a level of enforcement resources $c^* \in (\underline{c}, \bar{c})$, such that:*
i) For any enforcement policy $c < c^*$ the no-compliance equilibrium is risk dominant.
ii) For any enforcement policy $c > c^*$ the full-compliance equilibrium is risk dominant.
Furthermore, c^* is decreasing in η and is invariant to including the harm caused by non-compliance in the individuals' payoffs.

Proof. See the Appendix ■

For each level of enforcement resources, risk dominance makes one of the equilibria focal, but which one depends on resources being above or below a level[15] of enforcement resources c^*. In particular, c^* is increasing in χ, b and α, and decreasing in k and f .

Thus, whenever $\tilde{c} < c^*$ the externalities imply that more resources are needed to enforce the law. In contrast, whenever $\tilde{c} > c^*$ the externalities allow enforcement of the law with fewer resources. Having now a unique equilibrium per level of enforcement resources, the problem of the enforcement agency can be solved by maximizing social welfare.

Proposition 4 *In the presence of the externalities, equilibrium enforcement and compliance can be characterized as follows (incorporating the selected individuals' equilibrium)*[16]*:*
i) If $c^* \geq h$ the optimal enforcement resources are $c_{opt} = 0$, which yields a no-compliance equilibrium, $\mu^*_{opt} = 1$.
ii) If $c^* < h$ the optimal enforcement resources are $c_{opt} = c^*$, which yields a full-compliance equilibrium, $\mu^*_{opt} = 0$.

Proof. The proof is straightforward once the results from the previous proposition are inserted into the social welfare function. ■

[15] In order to ensure that $p(c^*, \mu) \leq 1$ for all μ, then I impose $b/f \leq \frac{1}{2} + \frac{(1-\eta)^{\chi}}{(2-\eta)^{\chi}}$. This condition guarantees that $c^* \leq ((1 + \mu - \eta)^{\chi}/k)$ which, as discussed in footnote (10), is the level of resources such that $p(c, \mu) = 1$.

[16] The same two subtle issues arise with respect to Proposition 4 as arose with Proposition 1; see the Appendix.

Therefore, there are values of h for which the externalities have relevant policy implications. Comparing this result with Proposition 1 illustrates the impact of the externalities on the optimal enforcement policy. First, for the case where $\tilde{c} < c^*$ and whenever $\tilde{c} < h < c^*$, it is optimal to enforce the law only when there are no externalities. The externalities increase the amount of resources needed to enforce the law to a level at which it is no longer socially optimal. This result illustrates situations that may happen in high crime neighborhoods; when the situation is considered to be "hopeless," some laws are no longer enforced. The model explains how the positive externality among criminals may be such that the law is too costly to be enforced.

Second, if $\tilde{c} < c^* < h$, the law is enforced both in the benchmark and when there are externalities, although more enforcement resources are needed in the latter case. Third, for the case where $\tilde{c} > c^*$ and whenever $c^* < h < \tilde{c}$, it is optimal to enforce the law only under the externalities. Finally, if $\tilde{c} > c^*$ and $c^* < \tilde{c} < h$, the law is enforced in both the benchmark and in the presence of the externalities, but now more enforcement resources are needed in the former case.[17]

Corollary 1 *The net effect of the externalities on enforcement is determined in equilibrium:*
i) When $\mu^*_{opt} = 1$, in equilibrium the net effect is negative ($p_\chi < 0$).
ii) When $\mu^*_{opt} = 0$, in equilibrium the net effect is positive ($p_\chi > 0$).

Intuitively, whether the net effect of the externalities is positive or negative in equilibrium depends on the compliance rate resulting from the optimal enforcement resources. If $\mu^*_{opt} < \eta$, then the equilibrium compliance is such that the net effect of the externality on the enforcement technology is positive. Alternatively, if $\mu^*_{opt} > \eta$ then in equilibrium the net effect of the externality on enforcement is negative. Hence, in equilibrium, two communities that differ only in their values of η may end up with different non-compliance rates. This result is particularly relevant since there exist policies that may affect the value of η. We analyze this type of policy in the next subsection.

4.3 Enforcing the law through community policing

Considering a technology with sensitivity to the externalities χ, this section analyzes what happens when the enforcement agency may influence the involvement of the community, η.

Proposition 5 *For any $h > 0$ there exists a large enough $\tilde{\eta} < 1$, above which enforcing the law becomes optimal for the agency. As a consequence, laws that were unenforced in the benchmark (because $h < \tilde{c}$), may be enforced in the presence of the externalities. The critical value $\tilde{\eta}$ might be decreasing or increasing in the sensitivity of the enforcement technology to the externalities, χ.*

[17] This result is in contrast to the claim by Bar-Gill and Harel (2001) that when a higher crime rate reduces the likelihood of the sanction, then the optimal investment in enforcement is always lower in the benchmark than in the model that incorporates the crime rate as a determinant of the expected sanction. They come to this conclusion because they fail to account for the fact that the probability of sanction function is different when there is an externality than when no externality exists. Essentially, the function has another argument that reflects the intensity of the externality, and they do not take account of this argument's independent influence on the probability of sanction function.

Proof. See the Appendix ■

Given the value of harm generated by non-compliance, h, and a technology with sensitivity to the externalities χ, it may not be optimal for the agency to enforce the law. However, the agency may reduce the necessary level of resources to enforce the law, c^*, by increasing η to $\tilde{\eta}$. In particular, the value of $\tilde{\eta}$ provides an index to measure the objective that community policing must accomplish.

The Neighborhood Watch Program created in 1972 is an example of the type of policies that promote communication between neighbors and the police in the United States. The purpose of this program is to reduce residential crime by involving citizens and private organizations in law enforcement activities. As the Neighborhood Watch Manual (elaborated by the United States' National Sheriffs' Association[18]) argues, "the impact of law enforcement alone is minimal when compared with the power of private citizens working with law enforcement." Efforts on community policing were encouraged through the US Violent Crime Control and Law Enforcement Act of 1994 (the Crime Act). According to the US Department of Justice (2001), five years later two thirds of U.S. local police departments had some type of community policing plan, many of them with full-time personnel performing community policing. The results obtained in this section provide a rationale for how these programs may have substantial effects if they succeed in increasing the communication between the police and the public.

In Europe, several countries have established community policing programs, for instance the *police de proximité* in France or the *Komunale Kriminalprävention* in Germany. However, as observed in Brogden and Nijhar (2005), "practice and understanding of the problem seem a long way" from the Anglo-American experience. Nevertheless, rising recorded crime rates and riots by ethnic minorities in France have prompted calls for a determined implementation of community policing. Recently, riots in Paris have focused attention[19] on the repeated call by local officials and residents for community policing.

4.4 Endogenous neighborhood involvement in enforcement

If a larger number of offenders in a community leads to a lower neighbors' involvement in enforcement, then the involvement will depend on μ. For instance, that is the case if violators can retaliate against those who provide information to the enforcement authority or if witnesses are intimidated. In some urban (generally high crime) communities of the United States, campaigns known as "Stop snitching" attempt to deter collaboration between neighbors and the police. To model this kind of situations, the involvement of a neighborhood must be endogenously determined.

Until now I have assumed that the involvement of a neighborhood in enforcement is exogenous, and measured by the parameter η. Consider now that the degree of involvement is a monotonically

[18] "Neighborhood Watch: A manual for citizens and for law enforcement" Available at http://www.usaonwatch.org.

[19] "Life still grim in French suburbs despite pledges," *Reuters*, November 27th, 2007 and "La police de proximité à nouveau au coeur des débats," *Le Monde*, November 27th, 2007.

decreasing[20] function n of μ such that $n(\mu) \in [0,1)$ for all μ. Then, the probability of the sanction is given by:

$$P = p(c,\mu) = kc^{\alpha}/(1+\mu-n(\mu))^{\chi} \tag{10}$$

where $p_{\mu} < 0$ since $n'(\cdot) \leq 0$.

Notice that introducing function n does not alter any of the definitions. The equilibrium condition for the individuals' behavior still implies that:

$$\mu^{*}(c) = \begin{cases} 0 \text{ if } p(0,c) > b/f \\ \hat{\mu} \text{ if } p(\hat{\mu},c) = b/f \\ 1 \text{ if } p(1,c) < b/f \end{cases}, \tag{11}$$

where now, given c, $\hat{\mu}$ satisfies $\hat{\mu} - n(\hat{\mu}) = (fkc^{\alpha}/b)^{1/\chi} - 1$ for $\chi > 0$. Since n is a monotone function of μ, then $\hat{\mu} - n(\hat{\mu})$ is monotone and increasing in $\hat{\mu}$. Thus, for each level of enforcement resources, c, there is a unique $\hat{\mu}$ satisfying $\hat{\mu} - n(\hat{\mu}) = (fkc^{\alpha}/b)^{1/\chi} - 1$. Moreover, $\hat{\mu}$ is increasing in c as in the exogenous involvement case.

Using the definitions for minimal and maximal resources needed to reach $P = b/f$ then, under an endogenous involvement of the neighborhood, they are $\underline{c} = (b(1-n(0))^{\chi}/fk)^{1/\alpha}$ and $\bar{c} = (b(2-n(1))^{\chi}/fk)^{1/\alpha}$, respectively. Notice that $\underline{c} \leq \tilde{c} < \bar{c}$ still holds. Therefore, as with the exogenous neighborhood involvement, multiple equilibria arise for enforcement resources in the interval[21] $c \in [\underline{c}, \bar{c}]$, as shown in the following proposition.

Proposition 6 *When the neighborhood involvement is endogenous, Proposition 2 still holds. Furthermore, the interval* $[\underline{c}, \bar{c}]$ *is increasing in the spread between* $n(0)$ *and* $n(1)$*, for* $n(0)$ *or* $n(1)$ *held fixed.*

Proof. See the Appendix. ■

Notice that $n(0) - n(1)$ measures the change in the neighbors' involvement when the no-compliance rate switches from no-compliance to full compliance. Thus, a larger change in the involvement leads to a larger range of enforcement resources for which there are multiple equilibria.

[20] In contrast, Huck and Kosfeld (2007) consider a model where new members' recruitment for a neighborhood watch program is easier when there is a "crime crisis." In such a framework, a higher number of burglaries makes it more likely for neighbors to be enrolled in the neighborhood watch program, which leads to a higher probability of catching a burglar. Their model differs from mine in several aspects; in particular, it evaluates the optimal magnitude of the sanction rather than the optimal level of enforcement resources, and it does not allow for congestion. Nevertheless, I may adjust my model to study a framework analogous to theirs. Assuming that neighbors' involvement is increasing in the crime rate (and excluding the congestion effect) I would have that:

$$p(c,\mu) = kc^{\alpha}/(1+n(\mu))^{\chi}$$

where $n(\mu)$ would be increasing in μ rather than decreasing; hence, there would be a negative externality among offenders. While this negative externality is certainly possible, it would predict a negative correlation in criminal behavior (as in footnote (8)'s case), which seems to be at odds with the available evidence.

[21] Notice that $\underline{c} < \bar{c}$ since $1 - n(0) < 2 - n(1)$. Also, notice that $\underline{c} \leq \tilde{c} < \bar{c}$ still holds.

The payoffs for individual i are shown in Table 2. Following the same steps as in Section 4.2, I find the risk dominant equilibrium for each level of enforcement resources in the interval $[\underline{c}, \bar{c}]$.

PAYOFFS FOR INDIVIDUAL i		Representative individual: COMPLY	Representative individual: NOT COMPLY
Individual i	COMPLY	0	0
	NOT COMPLY	$b - \frac{kfc^{\alpha}}{(1-n(0))^{\chi}}$	$b - \frac{kfc^{\alpha}}{(2-n(1))^{\chi}}$

Table 2: Payoffs for individual i when the involvement is endogenous, $\eta = n(\mu)$

Proposition 7 *For an endogenous neighborhood involvement described by function n, there exists a level of enforcement, c^*_{endog} , such that:*
i) For any enforcement policy $c < c^*_{endog}$ the no-compliance equilibrium is risk dominant.
ii) For any enforcement policy $c > c^*_{endog}$ the full-compliance equilibrium is risk dominant.
Furthermore, c^*_{endog} is decreasing in $n(1)$ and in $n(0)$. Therefore, $c^*_{endog} > c^*$ if the exogenous η in c^* is equal to $n(0)$ and above $n(1)$.

Proof. As shown in the Appendix, the proof is almost identical to the proof in Proposition 3. ■

As in Proposition 3, for each level of enforcement resources, risk dominance makes one of the equilibria focal. However, the threshold level[22] of resources c^*_{endog} depends now on $n(1)$ and $n(0)$. In particular, a lower level of neighborhood's involvement under no compliance, $n(1)$, results in a higher c^*_{endog} needed to enforce the law. Likewise, a lower level of neighborhood's involvement under full-compliance, $n(0)$, results in a higher c^*_{endog}.

Having a unique equilibrium per level of enforcement resources, I can solve the problem of the enforcement agency as in Proposition 4. Specifically, a small enough $n(1)$ may result in $c^*_{endog} > h$, which implies that the optimal resources are zero. Therefore, as the model illustrates, campaigns like "Stop Snitching" can clearly cause an increase in the resources needed for enforcement. Furthermore, enforcement may become non-optimal because of a decrease in $n(1)$. The Baltimore police have launched[23] the counter-campaign "Keep talking" to prevent the negative consequences of a deterioration in the communication between police and neighbors.

5 Example: The externality caused solely by congestion

In this section I impose $\eta = 0$ to focus on the externality caused by congestion. Notice that congestion in enforcement activities does not arise exclusively at the neighborhood level. For instance, after detection has taken place, there may be congestion in the administrative or court

[22] As with c^*, in order to ensure that $p(c^*_{endog}, \mu) \leq 1$ for all μ, then I impose $b/f \leq \frac{1}{2} + \frac{(1-n(0))^{\chi}}{(2-n(1))^{\chi}}$.
[23] "Police Counter Dealers DVD With One Of Their Own," *New York Times*, May 11th 2005.

procedures that ensure punishment. The "technology" of these procedures is commonly determined at the city or state level; therefore, crime rates' divergences observed across cities or states may be due to congestion, as shown in this section.

Since $\eta = 0$, P is given by:

$$P = p(c, \mu) = kc^{\alpha}/(1 + \mu)^{\chi}; \tag{12}$$

hence, $p_{\chi} < 0$ for all μ. The benchmark's results in Section 3 still hold for the case with no externality, $\chi = 0$. Figure 2 compares the equilibria for both the benchmark and the case of congestion. Since congestion has a negative effect on enforcement, all the new equilibria that arise under the externality for $c \in [\underline{c}, \bar{c}]$ are no-compliance equilibria.

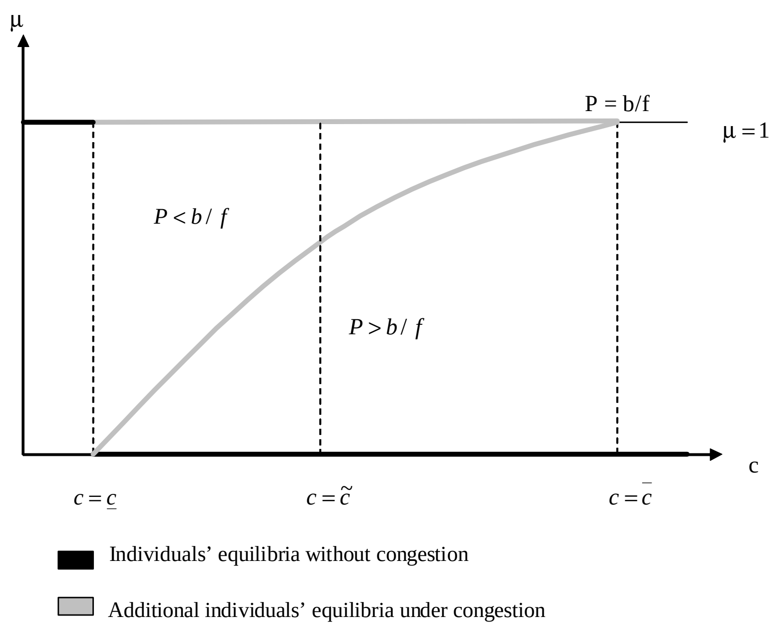

Figure 2: Equilibria of the individuals when $\eta = 0$

Using the equilibrium selection results, there is a $c^* \in (\underline{c}, \bar{c})$ such that for any $c > c^*$, the full compliance equilibrium is selected. The main difference of this example with respect to the general model is that now $\partial c^*/\partial\chi > 0$ (recall that for $\eta > 0$ the sign of this partial derivative was ambiguous). As a consequence, the more sensitive is the enforcement technology to congestion, the higher the amount of resources that are needed to induce the full-compliance equilibrium. Thus, identical locations differing only in how sensitive their technology is to the externality, require different amount of resources to induce compliance since c^* is increasing in χ.

Moreover, a high enough χ implies that the enforcement agency optimally chooses not to enforce the law because of the effect of congestion. This will be the case whenever χ is such that $c^* > h$. Thus, the externality caused by congestion has substantial effects on its own. First, if the externality exists and it is not accounted for, the optimal policy will not be correctly specified. Second, and more importantly, if it is possible to decrease the sensitivity of the technology to this externality, then the amount of resources needed for enforcement will be lower. Decreasing the sensitivity of the technology to congestion is possible by decreasing the amount of enforcement resources that are specifically needed for activities related to punishment.[24] For example, if punishment could take place instantaneously at the moment of detection, then resources would only be needed for detecting violators (e.g., there would be no need for tow trucks), which reduces considerably the possibility of congestion.

Examples of policies aimed at reducing the resources needed specifically for punishing activities are: incentives for voluntary payment of fines; demerit point systems for traffic violations;[25] or allowing for plea bargaining in criminal cases. More recently, the use of information and computer technology may become an effective way of reducing the need of resources for punishing activities. Electronic citation programs and other forms of electronic processing technology programs are being adopted throughout the United States, as assessed by the Department of Transportation (2003).

According to a report of the International Association of Chiefs of Police (2003), the use of electronic citations is recommended because "the physical process of writing and issuing traffic citations demands a significant amount of time and effort" from the patrol's officer, the offices' personnel and the court office staff. In addition, electronic processing programs allow drivers to pay tickets using the Internet, which also provides incentives for voluntary payment. Therefore, the use of electronic citations reduces considerably the amount of resources specifically needed for punishment. In Europe, the European Commission launched in 2005 the project Fully Automatic Integrated Road Control to promote the use of this type of technology. However, most European countries are being very slow in adopting these techniques into traffic management. As studied in this section, the benefit of this type of technology may be large.

6 Heterogeneous individuals

In this section, I assume that the benefit from violating the law follows a uniform distribution in the interval [0,1]. This extension allows me to examine how the effects of the externalities remain when the individuals are not homogenous. Since b follows a uniform distribution, the non-compliance rate is given by:

$$\mu(c) = \int_{p(c,\mu)}^{1} db = 1 - f \cdot p(c,\mu) = 1 - \frac{fkc^{\alpha}}{(1+\mu-\eta)^{\chi}}. \tag{13}$$

Let $c(\mu;\chi,\eta)$ be the level of enforcement resources that induce a non-compliance rate of μ given a technology with a sensitivity to the externalities, χ, and a neighborhood with involvement, η.

[24] Recall that, as explained in Section 2.3, in the enforcement process resources are used for activities related to detection, apprehension and punishment.

[25] Demerit point systems associated to traffic regulation are becoming a popular policy. Punishment is more immediate than with traditional fines. Since the agency administers the number of points of each driver, the punishment becomes effective by simply reducing the number of points of the violator.

Then:

$$c(\mu; \chi, \eta) = \left(\frac{(1-\mu)(1+\mu-\eta)^{\chi}}{fk} \right)^{1/\alpha}. \tag{14}$$

If the technology is not sensitive to the externalities (i.e., $\chi = 0$) then $c(\mu; 0, \eta) = ((1-\mu)/fk)^{1/\alpha}$ which is a one-to-one function of μ. The externalities introduce distortions in the level of enforcement resources needed to reach a specific non-compliance rate. Also, multiple equilibria arise when $c(\mu; \chi, \eta)$ is not a one-to-one function of μ. This is because if $c(\mu; \chi, \eta)$ is not monotone in μ, the same level of enforcement resources may induce more than one non-compliance rate.

Proposition 8 *For $\mu > \eta$ ($\mu < \eta$) enforcement is more (less) costly with the externalities (i.e., $\chi > 0$) than without them (i.e., $\chi = 0$). Furthermore, for $\chi > 1-\eta$ the externalities lead to multiple equilibria.*

Proof. See the Appendix ■

Figure 3 shows the equilibria of the individuals for the case where multiple equilibria arise (i.e., for $\chi > 1-\eta$). I denote as $[\underline{C}, \bar{C}]$ the interval of enforcement resources for which multiple equilibria arise. Since individuals differ now in their benefit from violating the law, b, definitions 3 and 4 do not apply here. Instead, $\underline{C}$ is the minimal enforcement resources needed to reach $\mu^* = 0$ as an equilibrium. That is, $\underline{C} = c(0; \chi, \eta)$ which implies $\underline{C} = ((1-\eta)^{\chi}/fk)^{1/\alpha}$. Then, for any level of enforcement resources $c > \underline{C}$, $\mu^* = 0$, is a possible equilibrium, although there may be others. Finally, $\bar{C}$ is the maximal level of enforcement resources for which a compliance rate $\mu^* > 0$ is an equilibrium, in other words $\bar{C}$ is the maximum of $c(\mu; \chi, \eta)$. Thus, for $c > \bar{C}$, $\mu^* = 1$ is the unique equilibrium.

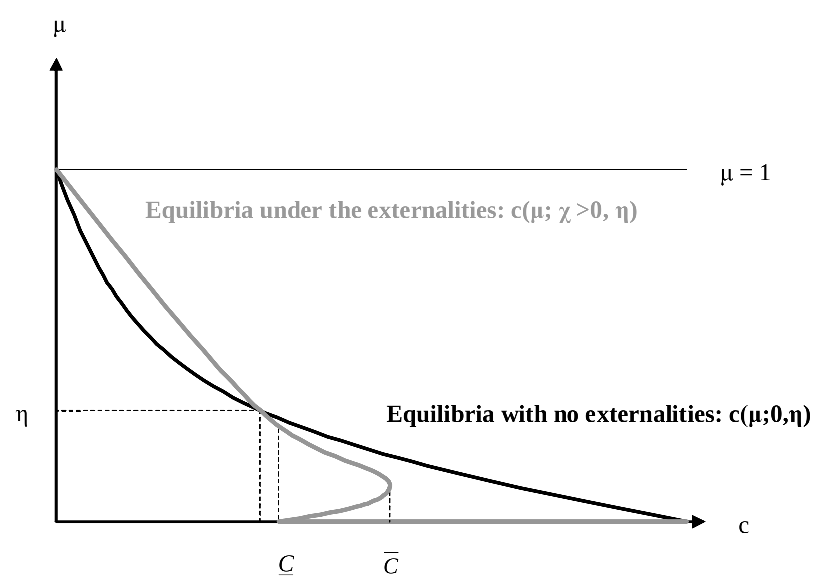

Figure 3

7 Conclusion

This paper studies externalities that affect the productivity of enforcement resources. The first externality is due to congestion of enforcement resources, which creates a positive externality among offenders by decreasing the probability of the punishment. The second externality is determined by the community's involvement in enforcement activities. Neighborhoods with a higher degree of involvement lead to a higher productivity of enforcement resources. When the involvement of the neighborhood is decreasing in the number of offenders, an additional positive externality among offenders arises.

These two externalities explain the interdependence of individuals' decisions to break the law, and generate neighborhood effects. Multiple equilibria arise for a given level of enforcement resources. Using risk dominance to select among the equilibria, I show how the externalities affect the optimal compliance rate and the optimal level of enforcement resources. When the net neighborhood effect is negative and strong enough, it may be too costly to enforce the law in that neighborhood.

While a significant number of empirical studies[26] have established the importance of neighborhood effects on crime, the issue has been largely neglected in theoretical models on enforcement. This paper provides a theoretical framework that explains how neighborhood effects may be related to the productivity of the enforcement technology. In relation to particular residential policies, the model allows for a better understanding of community policing and its consequences.

The results are extended to a framework where individuals are heterogeneous in the benefit from breaking the law which follows a uniform distribution. Alternative distribution functions are left for further research; however, multiple equilibria and similar conclusions are expected. Future progress in game theory is needed to find an equilibrium selection concept that can be applied to the framework with heterogeneous individuals.

Further research could also measure the impact of the externalities. However, important methodological problems[27] arise when trying to study neighborhood effects (such as selection bias or how to determine the boundaries of local communities). More importantly, differences in the technology's sensitivity to congestion and in the community's involvement in enforcement activities are hard to observe and measure. Nevertheless, this paper provides a rational explanation for the interdependence of individuals' decisions to break the law, which is a stylized fact that has already been shown empirically.

[26] For a survey see Sampson et al (2002).

[27] Again see Sampson et al (2002).

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APPENDIX

Two subtle issues with respect to Proposition 1

First, in part i), there is another equilibrium when $\tilde{c} = h$, in which $c_{opt} = \tilde{c}$ and $\mu^*_{opt} = 0$. This is because the enforcement agency is indifferent between spending $c_{opt} = 0$ and obtaining the no-compliance equilibrium $\mu^*_{opt} = 1$, and spending $c_{opt} = \tilde{c}$ and obtaining the full-compliance equilibrium $\mu^*_{opt} = 0$. But $\mu^*_{opt} \in [0,1]$ are all individuals' equilibria following $c_{opt} = \tilde{c}$. Thus, the equilibrium in which $c_{opt} = \tilde{c}$ relies crucially on the individuals' playing $\mu^*_{opt} = 0$ in response. The expectation of any minor deviation or tremble on the part of the individuals would cause the agency to prefer $c_{opt} = 0$, and thus, I ignore this second equilibrium when $\tilde{c} = h$.

The second subtle issue is that, in part ii), $\mu^*_{opt} \in [0,1]$ are all individuals' equilibria following $c_{opt} = \tilde{c}$. However, since $\tilde{c} < h$, the agency will be willing to spend $c_{opt} = \tilde{c} + \varepsilon$ (for vanishingly small ε) in order to induce the (unique) individuals' equilibrium $\mu^*_{opt} = 0$.

Proof of Proposition 2:

i) If $\chi = 0$, then $p(\tilde{c}) = b/f$ by definition of $\tilde{c}$. Then, $\mu^* = 1$ is the only equilibrium for any $c \leq \tilde{c}$. Alternatively, $\mu^* = 0$ is the only equilibrium for any $c \geq \tilde{c}$. If $\chi > 0$, then $p(\tilde{c}, 0) = b/(f(1-\eta)^{\chi}) > b/f$. Thus, $\mu^* = 0$ is an equilibrium when $c \geq \tilde{c}$. Also, $p(\tilde{c}, 1) = b/(f(2-\eta)^{\chi}) < b/f$. Thus, $\mu^* = 1$ is an equilibrium when $c \leq \tilde{c}$.

ii) By definition of $\bar{c}$, whenever $\chi > 0$ then $b - p(c,1) \cdot f > 0$ for $c < \bar{c}$ (and $b - p(c,1) \cdot f = 0$ for $c = \bar{c}$). Therefore since $\tilde{c} < \bar{c}$, whenever $\chi > 0$ it is also optimal for each individual to break the law if all others do when $c \in [\tilde{c}, \bar{c}]$; hence, $\mu^* = 1$ is an equilibrium. Similarly, by definition of $\underline{c}$, whenever $\chi > 0$ then $b - p(c,0) \cdot f < 0$ for $c > \underline{c}$(and $b - p(c,0) \cdot f = 0 \; for \; c = \underline{c}$). Therefore since $\tilde{c} \geq \underline{c}$, whenever $\chi > 0$ it is also optimal for each individual to comply if all others do; hence, $\mu^* = 0$ is an equilibrium.

With respect to the partial compliance equilibrium, if $\chi > 0$ then $c \in [\underline{c}, \bar{c}]$ implies $p(c, \hat{\mu}(c)) = \frac{b}{f}$ and hence $b - p(c, \hat{\mu}(c)) \cdot f = 0$. Recall that $\hat{\mu}(c) = \left(\frac{fkc^{\alpha}}{b}\right)^{1/\chi} - 1 + \eta$, where $\hat{\mu}(c) \in [0,1]$ for $c \in [\underline{c}, \bar{c}]$. Then, $p(c, \hat{\mu}(c)) - b/f$ and individuals are indifferent between complying and not complying. Thus, an equilibrium arises when a proportion of people $\hat{\mu}(c)$ breaks the law while a proportion of people $1 - \hat{\mu}(c)$ complies with it.

Notice that for any $\mu' \in (0,1)$ such that $\mu' \neq \hat{\mu}(c)$, $p(c, \mu') \neq \frac{b}{f}$ and therefore $\hat{\mu}(c)$ is the only equilibrium in which some individuals comply and other do not.

Finally, $\underline{c} - \bar{c} = (b/fk)^{1/\alpha}((2-\eta)^{\chi/\alpha} - (1-\eta)^{\chi/\alpha})$, which is increasing in χ.

Proof of Proposition 3:

As shown in Table 1, individual i and the representative individual play a 2x2 coordination game. Therefore, an equilibrium is reached when both players choose the same strategy. To measure the deviation loss of individual i, let λ be the probability that the representative individual chooses the compliance equilibrium.

When being at the no-compliance equilibrium, individual i faces a loss $\lambda(b - fkc^{\alpha}/(1-\eta)^{\chi})$, since the representative individual may deviate to comply. Also, individual i obtains a payoff of zero in case of deviating to comply. Then individual i chooses not to comply as long as:

$$\lambda\left(b-\frac{fkc^{\alpha}}{(1-\eta)^{\chi}}\right)+(1-\lambda)\left(b-\frac{fkc^{\alpha}}{(2-\eta)^{\chi}}\right)\geq 0.$$

That is, as long as:

$$\lambda\leq\frac{(b(2-\eta)^{\chi}-fkc^{\alpha})(1-\eta)^{\chi}}{fkc^{\alpha}((2-\eta)^{\chi}-(1-\eta)^{\chi})}.$$

Denoting the highest probability for which this condition holds (i.e., the highest for which i chooses to not comply) as $\bar{\lambda}$, then:

$$\bar{\lambda}=\frac{(b(2-\eta)^{\chi}-fkc^{\alpha})(1-\eta)^{\chi}}{fkc^{\alpha}((2-\eta)^{\chi}-(1-\eta)^{\chi})}.$$

Similarly, when being at the full compliance equilibrium, I denote as γ to the probability that the representative individual deviates to not comply. Then individual i chooses to comply only as long as the payoff from deviating is lower than the zero payoff from maintaining non-compliance. That is, as long as:

$$(1-\gamma)\left(b-\frac{fkc^{\alpha}}{(1-\eta)^{\chi}}\right)+\gamma\left(b-\frac{fkc^{\alpha}}{(2-\eta)^{\chi}}\right)\leq 0.$$

Then:

$$\gamma\leq\frac{(fkc^{\alpha}-b(1-\eta)^{\chi})(2-\eta)^{\chi}}{fkc^{\alpha}((2-\eta)^{\chi}-(1-\eta)^{\chi})}.$$

Denoting the highest probability for which this condition holds (i.e., the highest for which i chooses to comply) as $\bar{\gamma}$, then:

$$\bar{\gamma}=\frac{(fkc^{\alpha}-b(1-\eta)^{\chi})(2-\eta)^{\chi}}{fkc^{\alpha}((2-\eta)^{\chi}-(1-\eta)^{\chi})}.$$

Therefore, for individual i to comply risk dominates not to comply whenever $\bar{\gamma}>\bar{\lambda}$. That is, if:

$$c>\left(\frac{2b(1-\eta)^{\chi}(2-\eta)^{\chi}}{((2-\eta)^{\chi}+(1-\eta)^{\chi})fk}\right)^{1/\alpha}.$$

Meanwhile, not to comply risk dominates to comply whenever $\bar{\lambda}>\bar{\gamma}$, that is, in the rest of cases. Let c^* be the threshold amount of enforcement resources, then:

$$c^*=\left(\frac{2b(1-\eta)^{\chi}(2-\eta)^{\chi}}{((2-\eta)^{\chi}+(1-\eta)^{\chi})fk}\right)^{1/\alpha}.$$

Thus, for any $c<c^*$ the risk dominant strategy for player i is not to comply. Since every player faces the same setup and the same payoff function, for any $c<c^*$ the equilibrium selected is the no-compliance equilibrium. Similarly, for $c>c^*$ the equilibrium selected is the full-compliance equilibrium.

Notice that for all $\chi \in (0,1]$ it is the case that $c^* \in (\underline{c}, \bar{c})$. More precisely:

$$c^* = \underline{c} \cdot \left(\frac{2(2-\eta)^\chi}{(2-\eta)^\chi + (1-\eta)^\chi} \right)^{1/\alpha},$$

where $\frac{2(2-\eta)^\chi}{(2-\eta)^\chi+(1-\eta)^\chi} > 1$ for all $\chi > 0$. Also:

$$c^* = \bar{c} \cdot \left(\frac{2(1-\eta)^\chi}{(2-\eta)^\chi + (1-\eta)^\chi} \right)^{1/\alpha},$$

where $\frac{2(1-\eta)^\chi}{(2-\eta)^\chi+(1-\eta)^\chi} < 1$ for all $\chi > 0$. Also, notice that $\frac{\partial c^*}{\partial \eta} < 0$.

Finally, c^* is invariant to including the harm caused by non-compliance into the individuals' payoffs . Notice that if non-compliance causes a harm $v_i(h\mu)$ to individual i, then the condition for i not to deviate from the non-compliance strategy is given by:

$$\lambda \left(b - \frac{fkc^\alpha}{(1-\eta)^\chi} \right) + (1-\lambda) \left(b - \frac{fkc^\alpha}{(2-\eta)^\chi} - v_i(h\mu) \right) \geq -(1-\lambda) v_i(h\mu).$$

which is equivalent to the condition imposed previously. It can be shown analogously for γ.

Proof of Proposition 5

From proposition 4 we know that it is optimal to enforce a law for any $h > 0$ if and only if $h > c^*$. Let $\tilde{\eta}$ be the value such that $h = c^*$. From proposition 4 we know that $\partial c^* / \partial \eta < 0$. . Hence for any $\eta \in (\tilde{\eta}, 1)$ it holds that $h > c^*$ (i.e., it is optimal to enforce the law).

The existence of $\tilde{\eta}$ in the interval $[0,1)$ is guaranteed since from the proof of proposition 4 we know that $c^* = \underline{c} \left(2(2-\eta)^\chi / ((2-\eta)^\chi + (1-\eta)^\chi) \right)^{1/\alpha}$. Therefore:

$$\lim_{\eta \to 1} c^* = 0 \quad \text{since} \quad \lim_{\eta \to 1} \underline{c} = 0.$$

Thus, for any $h > 0$, there exists $\tilde{\eta} \in (0,1)$, such that $c^* = h$. This holds for all $\chi \in (0,1]$. In the benchmark where the externalities have no effect, it is not optimal to enforce the law if $h < \tilde{c}$. However, when the technology is affected by the externalities, then increasing η above $\tilde{\eta}$ is enough to make $c^* < h$.

Now, the sign of $\frac{\partial \tilde{\eta}}{\partial \chi}$ can be obtained locally to $\eta = \tilde{\eta}(\chi)$ by applying the implicit function theorem:

$$\frac{\partial \tilde{\eta}}{\partial \chi} = -\frac{\partial c^* / \partial \chi}{\partial c^* / \partial \tilde{\eta}},$$

where $\frac{\partial c^*}{\partial \eta} > 0$ as shown in the proof of proposition 4. Therefore, $\frac{\partial \tilde{\eta}}{\partial \chi} < 0$ if and only if $\partial c^* / \partial \chi > 0$ which is only true for an interval of values of η.

Proof of Proposition 6

In the proof of Proposition 2, the results are shown for $\eta \in [0,1)$. Thus, introducing $n(\mu) \in [0,1)$ instead of η does not affect the results. In particular, for part i) notice that when $\chi > 0$, the

$p(\tilde{c},0) = b/(f(1-n(0))^\chi) > b/f$ and $p(\tilde{c},1) = b/(f(2-n(1))^\chi) < b/f$. For part ii), notice that when $\chi > 0$ and using the obtained new value for $\bar{c}$, then $b - p(c,1)\cdot f > 0$ for $c < \bar{c}$. Therefore, it is optimal for each individual to break the law if all others do; hence, $\mu^* = 1$ is an equilibrium. Similarly, when $\chi > 0$ and using the obtained new value for $\underline{c}$, then $b - p(c,0)\cdot f < 0$ for $c > \underline{c}$. Therefore, it is optimal for each individual to comply if all others do; hence, $\mu^* = 0$ is an equilibrium. With respect to the partial compliance equilibrium, if $\chi > 0$ then $c \in [\underline{c}, \bar{c}]$ implies $p(c, \hat{\mu}(c)) = \frac{b}{f}$ and hence $b - p(c,\hat{\mu})\cdot f = 0$. Let $\hat{\mu}(c)$ be the unique non-compliance rate that sastisfies $\hat{\mu} - n(\hat{\mu}) = \left(\frac{fkc^\alpha}{b}\right)^{1/\chi} - 1$ for a given c, where $\hat{\mu}(c) \in [0,1]$ for $c \in [\underline{c}, \bar{c}]$. Then, $p(c,\hat{\mu}(c)) - b/f$ therefore individuals are indifferent between complying and not complying. Thus, an equilibrium arises when a proportion of people $\hat{\mu}$ breaks the law while a proportion of people $1-\hat{\mu}$ complies with it.

Finally, $\underline{c} - \bar{c} = (b/fk)^{1/\alpha}((2-n(1))^{\chi/\alpha} - (1-n(0))^{\chi/\alpha})$, which is increasing in χ as in the exogenous case. In addition, denoting the difference $n(0) - n(1) > 0$ as d, I can rewrite $\underline{c} - \bar{c} = (b/fk)^{1/\alpha}((2+d-n(0))^{\chi/\alpha} - (1-n(0))^{\chi/\alpha})$. Then, $\underline{c} - \bar{c}$ is increasing in d when holding $n(0)$ fixed. Similarly, substituting $n(0)$ with $d + n(1)$, I find that $\underline{c} - \bar{c}$ is increasing in d when holding $n(1)$ fixed.

Proof of Proposition 7

Using the payoffs in Table 2, and using the same procedure as in Proposition 3, let λ_{endog} be the probability that the representative individual chooses the compliance equilibrium. When being at the no-compliance equilibrium, individual i faces a loss $\lambda_{endog}(b - fkc^\alpha/(1-\eta)^\chi)$, since the representative individual may deviate to comply. Also, individual i obtains a payoff of zero in case of deviating to comply. Then individual i chooses not to comply as long as:

$$\lambda_{endog}\left(b - \frac{fkc^\alpha}{(1-n(0)^\chi}\right) + (1-\lambda_{endog})\left(b - \frac{fkc^\alpha}{(2-n(1))^\chi}\right) \geq 0.$$

Similarly, when being at the full compliance equilibrium, I denote as γ_{endog} to the probability that the representative individual deviates to not comply. Then individual i chooses to comply only as long as the payoff from deviating is lower than the zero payoff from maintaining non-compliance. That is, as long as:

$$(1-\gamma_{endog})\left(b - \frac{fkc^\alpha}{(1-n(0))^\chi}\right) + \gamma_{endog}\left(b - \frac{fkc^\alpha}{(2-n(1)^\chi}\right) \leq 0.$$

Therefore, following the same steps as in the proof of Proposition 3, I find a threshold level of enforcement resources c^*_{endog} such that for $c < c^*_{endog}$ the full-compliance equilibrium is risk dominant, and for $c > c^*_{endog}$ the no-compliance equilibrium is risk dominant. In particular, I find that c^*_{endog} is given by:

$$c^*_{endog} = \left(\frac{2b(1-n(0))^\chi(2-n(1))^\chi}{((2-n(1))^\chi + (1-n(0))^\chi)fk}\right)^{1/\alpha}.$$

Notice that $\frac{\partial c^*_{endog}}{\partial n(1)} < 0$ and $\frac{\partial c^*_{endog}}{\partial n(0)} < 0$. Also, as in Proposition 3, $c^*_{endog} \in (\underline{c}, \bar{c})$ and , c^*_{endog} is invariant to including the harm caused by non-compliance into the individuals' payoffs.

Proof of Proposition 8

Comparing $c(\mu; \chi > 0, \eta)$ and $c(\mu; 0, \eta)$, we see that if $\mu > \eta$ a larger amount of resources are needed because of the externalities since $c(\mu; \chi > 0, \eta) > c(\mu; 0, \eta)$. Meanwhile, if $\mu > \eta$ less resources because $c(\mu; \chi > 0, \eta) > c(\mu; 0, \eta)$.

Also, whenever $\chi > 1 - \eta$ then $c(\mu; \chi > 0, \eta)$ is not a one-to-one function. Notice that $c(\mu; \chi, \eta)$ is a one-to-one function only if $\partial c(\mu; \chi, \eta)/\partial \mu < 0$ for all μ. However, there are values of χ and η for which this condition does not hold since:

$$\frac{\partial c(\mu; \chi, \eta)}{\partial \mu} = \frac{1}{\alpha} \left(\frac{1}{fk} \right)^{1/\alpha} (1-\mu)^{1/\alpha} (1 + \mu - \eta)^{\chi} \left(\frac{\chi}{1 + \mu - \eta} - \frac{1}{1 - \mu} \right),$$

where all the elements are non-negative, except the last term in parenthesis that might be positive or negative. In particular,

$$\partial c(\mu; \chi, \eta)/\partial \mu \begin{cases} > 0 \text{ if } \mu < & (\eta + \chi - 1)/(1 + \chi) \\ < 0 \text{ if } \mu > & (\eta + \chi - 1)/(1 + \chi) \end{cases} .$$

Thus, $\partial c(\mu; \chi, \eta)/\partial \mu < 0$ for all μ only if $\chi < 1 - \eta$. Whenever this condition holds, each level of enforcement resources c induces a unique non-compliance rate, μ. However, for $\eta > 1 - \chi$ then $c(\mu; \chi, \eta)$ is not a one to one function.