

Gangs and Crime Deterrence*

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Abstract

A framework is developed in which the formation of gangs — the criminal market structure — is endogenous. We examine the impact of crime deterrence in this framework. It is shown that for a given gang structure, an increase in deterrence reduces criminal output. However, under identifiable circumstances, an increase in deterrence can also lead to an increase in the number of competing criminal gangs and to an increase in total illegal output.

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I. Introduction

It is well known that consumers have access to illegal goods.¹ Indeed, well-structured criminal organizations, often involved in both the production and the distribution of those goods, make them widely available to consumers.² It is also well known that relative to perfect competition, a market dominated by a monopolist is welfare inferior as prices tend to be higher and output to be lower. Of course, this reasoning applies provided the market is that of a *good*. For goods that are not so desirable, this reasoning can be plainly wrong. For example, if a criminal organization is the sole producer of an illegal good, its equilibrium price and output are respectively higher and lower than those that would obtain under a more competitive market structure. If it is not possible to completely deter producers, and if one would like to minimize the output of illegal goods, having a unique producer then dominates alternative market structures. This idea was developed by Buchanan (1973). Of course, this nice argument begs the question: why are some illegal markets monopolized while others are more competitive? This paper attempts to answer this question by providing a framework in which gang formation is endogenous.³ Our analysis focuses on the impact of crime deterrence on gang structure. We assume that larger gangs are an easier target for the enforcement authorities than smaller gangs. It follows that for a given gang structure, an increase in deterrence may decrease output per gang. However, it may also induce a change in the gang structure, from less to more gangs, making it possible for total output to increase.⁴

¹ For example, the world production (and consumption) of cocaine is estimated at 220 tons per year, and that of opium at about 4 000 tons per year.

² Some well-known examples of such organizations include the Colombian cartel for cocaine, the Hell's Angels for most drugs in North America, and the Golden Triangle mafia for opium.

³ The standard framework in the literature on crime is based on the classic paper by Becker (1968) in which individuals make their decision to become criminals independently and operate on their own.

⁴ This paper does not offer normative results. However, if one was to derive optimal enforcement policies, he or she would have to take into account that more deterrence can lead to a larger quantity of illegal goods. For an analysis of optimal enforcement policies in an organized criminal market, but without endogenous gang formation as in the current paper, see Garoupa (2000).

This last phenomenon was observed in the past. For example, between 1970 and 1990, while the United States were engaged in a war against opium producing organizations, the production of opium more than quadrupled.⁵ Also, consider the American intervention in Columbia which lead to the dissolution of the Cali and Medellin drug cartels. After the dissolution of the cartels, the number of criminal organizations involved in the production of cocaine increased, total cocaine production in Columbia increased (which represents 75% of world production), the quality of the drug increased, and some organizations went on to diversify their activities (e.g. production of high quality heroin). All this could be attributed to a more competitive market resulting from a larger number (between 80 and 250) of (smaller) organizations.⁶

There is a literature on the economics of organized crime, but few contributions are directly related to our work. Some authors have proposed explanations for the existence of organized crime. For example, Skaperdas and Syropoulos (1995) compare the formation of criminal organizations with that of early governments. They suggest that gangs arise from an anarchist environment when coercion is exercised. There is also the view developed by Grossman (1995) in which governments and organized crime compete in the provision of certain goods. We abstract from such competition by focusing on the provision by the organized crime sector of an illegal good for which the government cannot (or do not want to) provide a legal substitute.

Fiorentini and Peltzman (1995) have described environments in which organized crime is likely to flourish. First, organized crime is more likely to be prevalent when there are economies of scale and monopolistic power in the supply of some illegal good. Our paper takes place in such an environment. The introduction of a fixed cost in our model creates the required economies of scale, and gangs do exercise some market power. A second standard feature of organized crime according to Fiorentini and Peltzman is that gangs often exercise violence against other firms of the legal and illegal sectors. For

⁵ On the production of opium, see the web site of the Schaffer Library on drug policy at <http://www.druglibrary.org/schaffer/History/ophs.htm>.

⁶ See *The Economist*, September 11 1999

example, Gambetta and Reuter (1995) show that criminal organizations can use violence to maintain their market power. In our model, we do not introduce violence explicitly. We note that the relationship between gang structure and violence is likely to be ambiguous. Indeed, an increase in the number of gangs means that more suppliers are ‘sharing’ a given demand, and such an intensification in competition may lead to an increase in violence. On the other hand, a small number of gangs is likely to translate into larger rents for each organizations, and because there is more at stake, violence may increase.

This paper is organized as follows. In next section, we present an overview of the model and we briefly discuss each of the two stages (gang formation and gang competition) of our overall game. The gang formation stage is the object of Section III. At this stage, anticipating the payoffs from various gang structures, individuals align themselves into gangs. In Section IV, we analyze the gang competition stage in which given a gang structure, gangs compete in an illegal good market. The equilibrium of the game as well as the impact of deterrence are discussed in Section V. We conclude in Section VI.

II. An Overview of the Model

Consider the following economy inhabited by three types of private agents and an authority (e.g. a government). First, there is a large number of potential consumers for a homogenous good that can only be purchased illegally. The aggregate inverse demand for this good is linear: $P = \beta - \gamma Q$, where Q is the quantity of the illegal good, P is its price, and $\beta, \gamma > 0$. It is assumed that no individual can be arrested and sanctioned for consuming the good.⁷ Second, there is a large number of criminal workers, each of them providing one unit of labour for a wage normalized to zero.⁸ Finally, there are three identical risk neutral criminal entrepreneurs, denoted A , B , and C , which are to be the

⁷ If we relaxed this assumption, the parameters of the demand would be affected, but not our results.

⁸ This could be because there is perfect competition among workers, and that each of them has a reservation wage of zero. The fact that the wage is zero does not affect the nature of our results. It will in turn implies that the marginal cost of production is zero, a common assumption in the industrial organization literature.

criminal gang leaders,⁹ and the most important actors in what follows. We denote by $E = \{A, B, C\}$ the set of criminal entrepreneurs. Criminal entrepreneurs will set up their businesses (gangs) to maximize their (expected) income.¹⁰

A criminal entrepreneur has two important decisions to make. The first decision, taken during what we call the *gang formation stage*, is to determine who he wants to operate a gang with. We assume that criminal entrepreneurs are members of one and only one gang. A *gang* is defined as a nonempty subset of E denoted G_j . A *gang structure* is defined as a partition of E and is denoted H and the set of all possible gang structures is denoted \mathbf{H} . In the second stage, the *gang competition stage*, the gangs will operate and make profits, which will accrue to the criminal entrepreneurs. We assume that the decisions of gang G_j are made cooperatively by its criminal entrepreneurs to maximize its total profits, $\Pi_{G_j}(H)$, from selling the illegal good. Note that profits depend on the gang structure reflecting the fact that other gangs affect the profits of gang G_j . We assume that the play across gangs is non-cooperative. Once the profits of gang G_j are realized, they are divided equally between its criminal entrepreneurs.¹¹ We denote by $\pi_i(H) = \Pi_{G_j}(H)/|G_j|$, $i \in G_j$, the expected income of criminal entrepreneur i if he is a member of gang G_j , possibly with other criminal entrepreneurs, the total number of them in gang G_j being given by $|G_j|$. Thus, $\pi_i(H)$ is the ultimate payoff of individual i , realized in the second stage, if gang structure H emerges from the first stage. Looking ahead from the first stage to the second stage, the three criminal entrepreneurs will have a set of preferences (payoffs) over all possible gang structures, $\pi_i(H)$ for all $H \in \mathbf{H}$. Based on these preferences, criminal entrepreneurs forms gangs in the gang formation stage which leads to an equilibrium gang structure, say H^* , and thus to an equilibrium

⁹ In what follows, we use the terms “entrepreneurs” and “leaders” interchangeably. The current analysis assumes that a gang cannot form without a criminal entrepreneur; this could be because the managerial skills of a leader cannot be dispensed with.

¹⁰ Using three criminal entrepreneurs, rather than some larger arbitrary number of them, is mainly for ease of exposition. Indeed, some of our results below would clearly hold for any number of criminal entrepreneurs. But we also have some results which would only be maintained by adding further restrictions to the model.

¹¹ This assumption is without consequences.

payoff for each player i , $\pi_i(H^*)$.

Once the gang structure has been determined, the gang competition stage begins during which the gang leaders must decide how much to produce. It is assumed that to produce, a gang must pay a fixed cost F .¹² To produce the illegal good, the gang must also hire criminal workers, each of them producing one unit of the illegal good. Because the wage of those workers is normalized to zero, the marginal cost of producing is zero. The number of workers hired by gang G_j , which equals its output, is denoted by n_j .

The government attempts to reduce gangs' criminal activity by sanctioning the gang leaders that it identifies. To identify those leaders, it tries to infiltrate the gangs with under-cover agents whose method is simply to join the pool of criminal workers and to try to be hired by a gang. Let α be some measure of the number of under-cover agents put on the streets by the government, a high (low) α reflecting a large (small) number of under-cover agents. The larger α , the larger the probability that the leaders of a given gang will be arrested, brought to court, found guilty, and sanctioned (from now on, we call this the probability of detection). But the probability of detection also depends on the number of criminal workers hired by the gang. The larger the number of workers hired by a gang, the more likely it will have hired an under-cover agent. Let $p(\alpha, n_j)$ be the probability that the leader(s) of gang G_j will be detected, where in the case of a gang with multiple leaders, all of them are detected once one of them is. As can be noticed, we assume, for simplicity, that the probability of detection for leaders of gang G_j is independent of the gang structure, of the behaviour of other gangs, or of the number of leaders in its rank. To simplify our analysis, we use a precise functional form for the probability of detection: $p(\alpha, n_j) = k\alpha n_j$, with $k > 0$. This functional form implies that $p_n > 0$, as is discussed above. But clearly, there could be real world cases in which $p_n < 0$, reflecting the fact that larger gangs are possibly better 'organized' and may therefore be more efficient at avoiding detection. Note that we are also assuming that $p_{n\alpha} > 0$, meaning that increased detection effort leads to a larger increase in the probability of detection for a gang with

¹² This could be to pay for the weapons necessary to protect gang members from other gangs, to corrupt local authorities, etc.

a larger output (i.e. with a larger number of criminal workers).¹³ We later discuss the impact of these assumptions on our results.

The leader(s) of a gang who are detected are imposed a sanction. Let $s_{|G_j|}$ denote the total sanction for gang G_j which has $|G_j|$ leaders (e.g. s_2 is the sanction imposed on a 2-leader gang). The sanction imposed on a gang is assumed to be equally borne by all its leaders. Therefore, the sanction per leader of gang G_j which has $|G_j|$ leaders is $s_{|G_j|}/|G_j|$.¹⁴ For simplicity, we assume that the per leader sanction is the same irrespective of the gang structure: $s_1 = s > 0$, $s_2 = 2s$, and $s_3 = 3s$.¹⁵

We now proceed with the analysis of the two stages, starting with the first, the gang formation stage.

III. The Gang Formation Stage

Starting with the set of criminal entrepreneurs E , we model how these players might choose to align themselves into gangs. We use the coalition formation approach of Burdidge *et al.* (1997), which was itself based on that of Hart and Kurz (1983).

Anticipating the gang competition stage, the players know $\pi_i(H)$ for all $H \in \mathbf{H}$ so they have a preference ordering over all possible gang structures. We use these preference

¹³ We think that our assumptions on the probability of detection are natural. Suppose there is a pool of potential employees consisting of W ‘true’ criminal workers and α under-cover agents. Suppose a gang picks a worker from this pool. Then, the probability of not hiring an under-cover agent (i.e. the probability of no-detection if we assume detection as soon as an under-cover agent is hired) is simply $W/(W + \alpha)$. For the case where a gang hires n workers, the probability of no-detection, say $q(\alpha, n_j)$, is the probability of hiring a true criminal worker on each draw. This probability can be written as $q(\alpha, n_j) = \prod_{i=1}^n [(W - i + 1)/(W + \alpha - i + 1)]$. It is easily shown that $q_n < 0$ and that $q_{n\alpha} < 0$. Since in such a framework, $p(\alpha, n_j) = 1 - q(\alpha, n_j)$, it follows that $p_n > 0$ and that $p_{n\alpha} > 0$.

¹⁴ Because criminal entrepreneurs are identical, the assumption of “equal sharing” is reasonable. It would be possible to relax it.

¹⁵ There are many possible interpretations of what we are here labeling a sanction. As is standard, a sanction could be some amount of money to be paid or some non-monetary cost (i.e. pure utility loss) imposed on the leaders by the authority after detection. It could also be the opportunity cost of an illegal transaction that did not take place because of detection. For our analysis to apply, it must be possible to ‘share’ a sanction and to establish its monetary equivalent.

orderings to construct a game in strategic form for this stage. We suppose that each criminal entrepreneur formulates a plan for joining partners to form a gang. A *strategy* of player i is a partnership plan in which i announces the gang to which he wants to belong. Formally, a strategy for player i is a subset of E , or G_i , with $i \in G_i$. A combination of strategies (one for each player) $g = (G_A, G_B, G_C)$ is a *strategy profile*. The set of all strategies for player i is denoted by \mathbf{G}_i , and $\mathbf{G} = \mathbf{G}_A \times \mathbf{G}_B \times \mathbf{G}_C$ will stand for the set of all strategy profiles.

How any given strategy profile $g \in \mathbf{G}$ gets reconciled into a resultant gang structure is summarized by a function, $\psi : \mathbf{G} \rightarrow \mathbf{H}$, called the *coalition structure rule*, which assigns to any $g \in \mathbf{G}$ a unique gang structure $H = \psi(g)$. Several such rules exist which are discussed in Burbidge *et al.* (1997). But for our purposes, we have selected the rule labeled the *similarity rule*. To save on notation, we assume that $\psi(\cdot)$ designates the similarity rule. Now, given any $i \in E$ and $g \in \mathbf{G}$, let $\psi_i(g)$ denote the gang to which i belongs in the gang structure $\psi(g)$ resulting from the profile g . Then, $\psi(\cdot)$ is the similarity rule if for any strategy profile $g \in \mathbf{G}$, and any $i \in E$, we have:

$$\psi_i(g) = \{j \in E | G_i = G_j\}$$

Thus, under the similarity rule, all players with the same partnership plan (i.e. same strategy) are in the same gang. In effect we are interpreting a player's partnership plan as the largest set of partners he is willing to be associated with in a gang.¹⁶

The *gang formation game* is now well-defined. The coalitional players are the set E of criminal leaders; the set of strategies available to each leader $i \in E$ consists of all possible partnership plans, \mathbf{G}_i ; every strategy profile g induces a gang structure $\psi(g)$ through the similarity rule, and thus a payoff for each leader $i \in E$ of $\pi_i(\psi(g))$.

The equilibrium outcome of our game will be a gang structure $H^* = \psi(g^*)$, where g^* is the *equilibrium strategy profile*. We now wish to identify this equilibrium strategy profile. For reasons discussed in Burbidge *et al.* (1997), the equilibrium concept we use in this analysis is that of *Coalition Proof Nash Equilibrium* (CPE), developed by Bernheim,

¹⁶ There is a unique g , denoted g^m , which leads to the formation of the grand gang: $g^m = \{E, E, E\}$. To assume otherwise would be to assume that a grand gang could form without unanimous consent.

Peleg and Whinston (1987), and which is a refinement of Nash equilibrium. The concept of CPE is intended to deal with the possibility of a group of players coordinating on a joint deviation if such a deviation is to make each deviating player better off. Then, a strategy profile is a CPE if no set of players, taking the strategies of its complement as fixed, can fashion a profitable deviation for each of its members that is itself immune to further deviations by subsets of the deviating coalition.¹⁷

IV. The Gang Competition Stage

Various equilibrium outcomes can emerge from the first stage. When the equilibrium outcome is the grand gang $H^* = \{\{A, B, C\}\}$, this single gang will act as a monopoly on the illegal good market. But if H^* contains two gangs (i.e. if $H^* = \{\{A, B\}, \{C\}\}$ or if $H^* = \{\{A, C\}, \{B\}\}$ or if $H^* = \{\{A\}, \{B, C\}\}$), these will compete as a duopoly. Finally, if the outcome is one with three singleton gangs ($H^* = \{\{A\}, \{B\}, \{C\}\}$), they will compete as a triopoly. We examine each of these in turn. Note that in all cases, we assume that deterrence cannot fully deter production; in other words, we assume that for each gang structure, detection and sanctions cannot be chosen so as to make it optimal for firms to stop producing.

IV.1 Monopoly

The problem of the leaders of the grand gang is to maximize total profits:

$$\max_n (\beta - \gamma n)n - F - 3k\alpha ns$$

From the first order condition, the solution to this problem is $n^m = (\beta - 3k\alpha s)/2\gamma$. Clearly, an increase in either the sanction $s_3 = 3s$ or in detection effort α leads to a decrease in production. After sharing, the profits for each leader are $\pi_i^m = (\beta - 3k\alpha s)^2/12\gamma - F/3$, which are also decreasing with the sanction and with detection effort.

¹⁷ For a formal definition, see Bernheim, Peleg and Whinston (1987).

IV.2 Duopoly

When the equilibrium structure entails two gangs, one is necessarily a singleton gang and the other a doubleton gang. The two gangs compete as a duopoly. We denote by n^s and n^d the production of the singleton and of the doubleton gangs, respectively. The first step is to find the reaction functions for each gang. For the singleton gang, the problem to solve is:

$$\max_n [\beta - \gamma(n + n^d)]n - F - k\alpha ns$$

while for the doubleton gang, it is:

$$\max_n [\beta - \gamma(n^s + n)]n - F - 2k\alpha ns$$

Solving for the Nash equilibrium yields $n^d = (\beta - 3k\alpha s)/3\gamma$ and $n^s = \beta/3\gamma$. Output is decreasing in the own sanction and in detection effort for the doubleton gang, but not for the singleton gang. However, because the singleton gang faces a smaller sanction, it produces more. The profits for each of the leaders of the doubleton gang are $\pi_i^d = (\beta - 3k\alpha s)^2/18\gamma - F/2$, while the profits for the leader of the singleton gang are $\pi_i^s = \beta^2/9\gamma - F$. Again, profits per leader are decreasing in the own sanction and in detection effort for the doubleton gang, but not for the singleton gang.

IV.3 Triopoly

The last possible gang structure is one with three singleton gangs. The three gangs compete as a triopoly. Let n_j^t denote the output of gang G_j . The problem of the leader of gang G_i , $i \neq k, \ell$, is:

$$\max_n [\beta - \gamma(n + n_k^t + n_\ell^t)]n - F - k\alpha ns$$

Solving for the Nash equilibrium and imposing symmetry so that $n_j^t = n^t$, $\forall j$, we find that $n^t = (\beta - k\alpha s)/4\gamma$, which is decreasing in the own sanction and in detection effort. The per leader profits are $\pi_i^t = (\beta - k\alpha s)^2/16\gamma - F$, which are also decreasing in the own sanction and in detection effort.

IV.4 Summary

In Figure 1, we present a summary of the payoffs for each criminal leader for the three types of gang structures.

Table 1: The payoffs under various gang structures

	π_A	π_B	π_C
$\{\{A, B, C\}\}$	$(\beta - 3k\alpha s)^2/12\gamma - F/3$	$(\beta - 3k\alpha s)^2/12\gamma - F/3$	$(\beta - 3k\alpha s)^2/12\gamma - F/3$
$\{\{A, B\}, \{C\}\}$	$(\beta - 3k\alpha s)^2/18\gamma - F/2$	$(\beta - 3k\alpha s)^2/18\gamma - F/2$	$\beta^2/9\gamma - F$
$\{\{A\}, \{B\}, \{C\}\}$	$(\beta - k\alpha s)^2/16\gamma - F$	$(\beta - k\alpha s)^2/16\gamma - F$	$(\beta - k\alpha s)^2/16\gamma - F$

We now turn to the analysis of the equilibrium of the overall game, and present our results regarding the impact of crime deterrence.

V. Equilibrium and the Impact of Crime Deterrence

Before turning to the description of the equilibrium, we first present a result which is in accord with conventional wisdom. Note that all proofs are in the Appendix.

Proposition 1: *Given a gang structure, an increase in detection effort α leads to a decrease in the illegal good total output.*

The important requirement for Proposition 1 to hold is that the gang structure *remains the same* after crime deterrence has increased. As we will now show, this is not guaranteed.

We now turn to a description of the equilibrium of the overall game. The following result can be obtained.¹⁸

¹⁸ The model of coalition formation used in this paper is that of Burbidge *et al.* (1997), itself based on that of Hart and Kurz (1983). An alternative approach has been developed in Ray and Vohra (1999). Each approach presents some advantages. For example, Ray and Vohra (1999)'s approach is more complex (a cost) but it endogenizes both the division of a

Lemma 1: *There exists two critical levels of the fixed cost, denoted \bar{F} and \tilde{F} , with*

$$\bar{F} = \frac{4}{3} \frac{\beta^2}{\gamma} - \frac{(\beta - 3k\alpha s)^2}{\gamma} > \tilde{F} = \frac{(\beta - k\alpha s)^2}{8\gamma} - \frac{(\beta - 3k\alpha s)^2}{9\gamma}$$

and such that:

- a) *If $F > \bar{F} > \tilde{F}$, then the equilibrium outcome is the grand gang;*
- b) *If $\bar{F} > F > \tilde{F}$, then the equilibrium outcome is a duopoly gang structure;*
- c) *If $\bar{F} > \tilde{F} > F$, then the equilibrium outcome is a triopoly gang structure.*

Thus, depending on the level of the fixed cost F relative to two critical levels, various equilibrium gang structures can obtain.¹⁹ The following result also obtains.

Lemma 2: *For β large enough relative to $k\alpha s$, the critical levels \bar{F} and \tilde{F} are increasing in the level of detection effort α .*

For the rest of this paper, we assume that β is large enough so that Lemma 2 holds. Then, combining Lemma 1 and 2, we can show our main result:

Proposition 2: *Starting from an equilibrium gang structure entailing the grand gang, increasing detection effort α will eventually lead to a switch to a duopoly gang structure; further increases in detection effort will lead to a switch to a triopoly gang structure.*

Thus, the gang structure responds to deterrence. The break-up of the monopoly when deterrence increases can be partly explained by our assumption that the increase in the probability of detection following an increase in deterrence is larger when output is larger ($p_{n\alpha} > 0$). *Ceteris paribus*, in a more competitive structure, output per gang is smaller, and so, the impact of an increase in deterrence on the probability of detection is smaller.

coalition's resources and the coalition structure rule (a benefit), which are exogenous in the current paper. In principle, the equilibria under these two approaches could differ. However, in the language of Ray and Vohra (1999), the game considered here generates a symmetric partition function (section 3 of their paper). In that case, applying Theorem 3.5 of Ray and Vohra (1999) yields the same equilibrium outcome as that described in Lemma 1, i.e. the two approaches are consistent in the specific model used here.

¹⁹ As is shown in the Appendix, a given equilibrium outcome can be the result of several equilibrium strategy profiles.

Note that if $p_{n\alpha} > 0$ did not hold, then starting from the monopoly structure, and increase in deterrence would ‘stabilize’ this gang structure — i.e. it would make less attractive any deviation from the grand gang. However, in such a case, a decrease in deterrence would possibly lead to a break-up in the gang structure. Thus, it is generally correct to say that whatever the sign of $p_{n\alpha}$, the gang structure may respond to deterrence.

There are factors that make a break-up of the gang structure more likely. Clearly, the larger the size of the change in deterrence, the more likely the gang structure will respond.²⁰ Also, a larger demand for the illegal good (as measured by a larger β and/or a smaller γ) magnifies the response of the gang structure to deterrence. Indeed, it is possible to show that starting from a monopoly, a given increase in α is more likely to induce a break-up of the monopoly when the demand is larger.²¹

Ultimately, an authority who would like to design an optimal deterrence policy should take the response of the gang structure into account. For example, if such an authority would like to minimize the illegal good total output, it would certainly benefit from understanding the following:

Corollary to Proposition 2: *Starting from an equilibrium gang structure entailing the grand gang, increasing detection effort α can lead to an increase in the illegal good total output.*

This result contradicts conventional wisdom. It says that an increase in crime deterrence can lead to more crime (as measured by output). This, of course, is due to the fact that by increasing deterrence, a monopoly is broken and the illegal good market is made more competitive. And as is well known, more competition implies larger quantities.

— FIGURES 1 AND 2 —

²⁰ This is because, for a given F , a larger change in α leads to a larger change in \bar{F} and \tilde{F} , making it more likely that F will switch from being smaller than \bar{F} (resp. \tilde{F}) to being larger than \bar{F} (resp. \tilde{F}).

²¹ This obtains because $\partial^2 \bar{F} / \partial \alpha \partial \beta > 0$ and $\partial^2 \tilde{F} / \partial \alpha \partial \gamma < 0$.

In Figures 1 and 2, we have depicted the relationship between total output and deterrence. In these figures, $\bar{\alpha}$ and $\tilde{\alpha}$ denote the levels of deterrence such that F equals \bar{F} and \tilde{F} , respectively. Thus, for $\alpha < \bar{\alpha}$ (low deterrence), the equilibrium gang structure is a monopoly, for $\bar{\alpha} \leq \alpha < \tilde{\alpha}$ (medium deterrence), it is a duopoly, and for $\alpha \geq \tilde{\alpha}$ (high deterrence), it is a triopoly. In both figures, it can be noted that for a given gang structure, output declines with deterrence, but also that output jumps when the equilibrium gang structure changes. Overall, and as in Figure 2, a break-up in the gang structure following an increase in deterrence may well lead to a level of output higher than any of those observed for lower levels of deterrence.

VI. Conclusion

Previous studies of criminal gangs have assumed a fixed market (or gang) structure. This paper's contribution has been to provide a framework in which gang structure is endogenous, thereby allowing for interesting and possibly counter-intuitive phenomena. Our framework may, for example, provide an explanation for the failure of the "war on drugs" launched in the 80's under the Reagan administration. If market structure is fixed, more deterrence clearly leads to a reduction in criminal output. But as is shown in our analysis, when the gang structure responds to deterrence, more deterrence may lead to an increase in criminal output if it makes the market more competitive. Such a phenomenon was shown to possibly obtain in an oligopolistic market of the type we observe in the real world (e.g. cocaine or heroine markets). The failures of several wars on drugs may be explained by such a turn of events.

VII. Appendix

Proof of Proposition 1: The grand gang produces n^m which is decreasing in α . Under the duopoly structure, total output is $n^s + n^d$ which decreases with α . Finally, total output is $3n^t$ under a triopoly structure, and this is also decreasing in α . ■

Proof of Lemma 1: \bar{F} is the fixed cost such that $\pi_i^m = \pi_i^s$ while \tilde{F} is such that $\pi_i^d = \pi_i^t$. Note that $\bar{F} > \tilde{F}$ if:

$$\frac{4}{3} \frac{\beta^2}{\gamma} - \frac{(\beta - 3k\alpha s)^2}{\gamma} > \frac{(\beta - k\alpha s)^2}{8\gamma} - \frac{(\beta - 3k\alpha s)^2}{9\gamma}$$

which, after some manipulations, reduces to $73(\beta - k\alpha s)^2 > 9(\beta - k\alpha s)^2 - 64(\beta - 3k\alpha s)^2$. It is easily shown that this must hold.

Next to prove part a), b), and c), consider the relative payoffs for the three possible levels of F .

Table A.1: Ranking of Payoffs when $F > \bar{F} > \tilde{F}$

	π_A	π_B	π_C
$\{\{A, B, C\}\}$	1	1	1
$\{\{A, B\}, \{C\}\}$	3	3	2
$\{\{A\}, \{B\}, \{C\}\}$	4	4	4

Table A.2: Ranking of Payoffs when $\bar{F} > F > \tilde{F}$

	π_A	π_B	π_C
$\{\{A, B, C\}\}$	2	2	2
$\{\{A, B\}, \{C\}\}$	3	3	1
$\{\{A\}, \{B\}, \{C\}\}$	4	4	4

Table A.3: Ranking of Payoffs when $\bar{F} > \tilde{F} > F$

	π_A	π_B	π_C
$\{\{A, B, C\}\}$	2	2	2
$\{\{A, B\}, \{C\}\}$	4	4	1
$\{\{A\}, \{B\}, \{C\}\}$	3	3	3

a) $F > \bar{F} > \tilde{F}$ (Table A.1)

From the strategy profile $g^m = (E, E, E)$, with $E = \{A, B, C\}$ (i.e. all individuals want to be in a grand gang), there is no profitable deviations as the payoffs in the first row (the equilibrium outcome for g^m) Pareto dominates those of the two other rows. Therefore, g^m is a CPE.

From any g which leads to the gang structures in rows 2 or 3, there are always profitable and credible deviations by the subset of players with $G_i \neq E$ to $G_i = E$. They are profitable (see Table A.1) and credibility is established by g^m being CPE. Therefore the unique CPE is g^m and the unique gang structure is the grand gang.

b) $\bar{F} > F > \tilde{F}$ (Table A.2)

From the strategy profile g^m , there is a profitable unilateral, and therefore credible deviation, by C , to $G_C = \{C\}$. From any g which leads to the triopoly gang structure $\{\{A\}, \{B\}, \{C\}\}$, there is at most one player with strategy E . If there is one player with strategy E , then this player, say A , and one of the other two, say B (as in Table A.1), have a profitable deviation to $G_A = G_B = \{A, B\}$. This deviation is also credible as there are no further profitable deviations for them (recall $G_C \neq E$). If no player has strategy E , then any two players, say A and B , have a profitable and credible deviation to $G_A = G_B = \{A, B\}$.

Therefore, if there is a CPE gang structure, it must be the duopoly gang structure. The profile $g = (\{A, B\}, \{A, B\}, \{C\})$ is immune to unilateral deviations as they are not profitable. As for a joint deviation by A and B to E , it would have no effect because under the similarity rule, the equilibrium gang structure would not change. Thus, $g =$

$(\{A, B\}, \{A, B\}, \{C\})$ is CPE, as are other profiles [e.g. $g' = (\{A, B\}, \{A, B\}, \{B, C\})$] leading to the duopoly gang structure. Thus, the unique CPE gang structure is the duopoly.

c) $\bar{F} > \tilde{F} > F$ (Table A.3)

From the strategy profile g^m , there is a profitable unilateral, and therefore credible deviation, by C , to $G_C = \{C\}$. From any g which leads to the duopoly gang structure $\{\{A, B\}, \{C\}\}$, there are profitable unilateral, and therefore credible deviations, by A to $G_A = \{A\}$, and by B to $G_B = \{B\}$.

Therefore, if there is a CPE gang structure, it must be the triopoly gang structure. The profile $g = (\{A\}, \{B\}, \{C\})$ is immune to unilateral deviations and to 2-player deviations because they are not profitable. A joint deviation by all players to E is not credible as C would have an incentive to further deviate to $G_C = \{C\}$. Thus, $g = (\{A\}, \{B\}, \{C\})$ is CPE, as are other profiles [e.g. $g' = (\{A, B\}, \{B\}, \{C\})$] leading to the triopoly gang structure. Thus, the unique CPE gang structure is the triopoly.

This completes the proof. ■

Proof of Lemma 2: The result is obtained by differentiating \bar{F} and \tilde{F} with respect to α . First, $\partial\bar{F}/\partial\alpha = 6ks(\beta - k\alpha s)/\gamma$ which is positive since $n^t = (\beta - k\alpha s)/4\gamma$. Second, note that $\partial\tilde{F}/\partial\alpha = 2ks\{[(\beta - 3k\alpha s)/3\gamma] - [(\beta - k\alpha s)/8\gamma]\}$. Routine manipulations show that $\partial\tilde{F}/\partial\alpha > 0$ if $\beta > 4.2k\alpha s$, i.e. $\partial\tilde{F}/\partial\alpha > 0$ for β large enough relative to $k\alpha s$. ■

Proof of Proposition 2: Starting from $F > \bar{F} > \tilde{F}$, and by Lemma 2, increasing α will eventually lead to $\bar{F} > F > \tilde{F}$. Further increases will then lead to $\bar{F} > \tilde{F} > F$. That the gang structure changes then follows from Lemma 1. ■

Proof of Corollary to Proposition 2: From Proposition 2, a marginal increase in α when $F = \bar{F}$ will induce a switch from the grand gang to the duopoly gang structure. Output will therefore go from $n^m = (\beta - 3k\alpha s)/2\gamma$ to $n^s + n^d = (2\beta - 3k\alpha s)/3\gamma > n^m$. Also, an increase in α when $F = \tilde{F}$ will induce a switch from the duopoly to the triopoly gang structure. Output will therefore go from $n^s + n^d = (2\beta - 3k\alpha s)/3\gamma$ to $3n^t = 3(\beta - k\alpha s)/4\gamma > n^s + n^d$. ■

VIII. References

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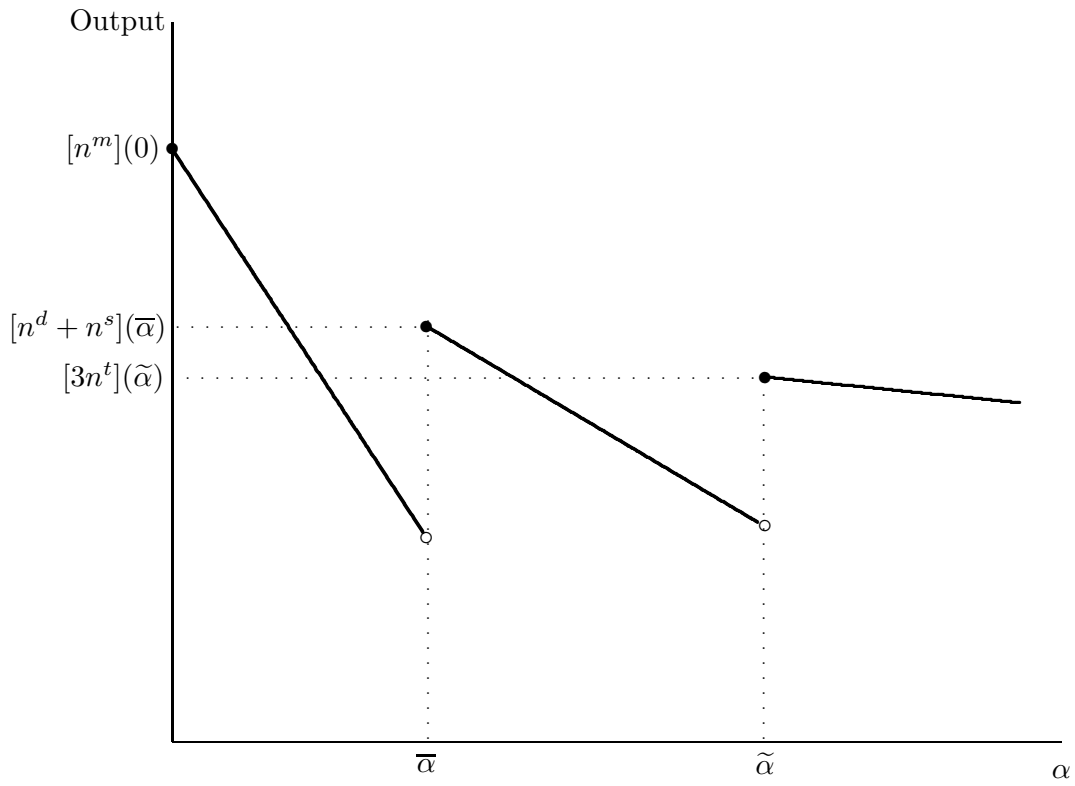


Figure 1

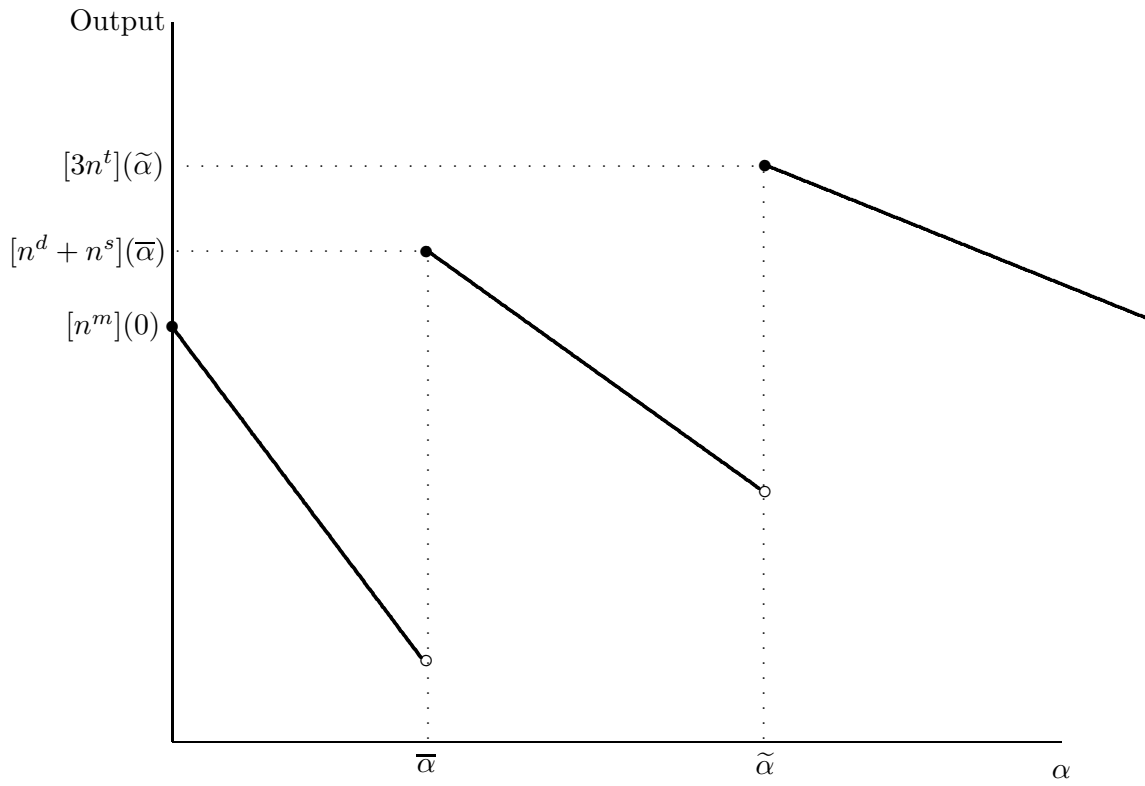


Figure 2