

‘Property rights’ in illicit drug markets*

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July 21, 2018

Abstract In this paper we study a situation in which an agreement among criminals, resembling property rights’ enforceability on its effect to the economic allocation, can emerge in illicit drug markets. In our main result, we use the *mechanism design approach* to show that a change inside the prison system, from a competitive environment to the hegemony of a group of criminals, implies the subgame-perfect Nash equilibrium (SPNE) in illicit markets outside prison to shift from warfare to peace among market dealers. Specifically, the hegemonic group of criminals is shown to *desire* and *to be able to promote* a collusive agreement among dealers under which no violence is performed. This contrasts with the SPNE under no hegemony inside prison system, in which the possibility to expel others from the market is shown to drive violence up to a positive level. The main testable implication of our theory is not rejected in the data from São Paulo, the richest state in Brazil. In statistical terms, correlation between violent crimes and drug dealing is positive before the change inside the prison system and inexistent after it. Our result is relevant for public policy since it shows that legalizing profitable illicit activities would not have the expected effect (reduction on the activity-related violence) if property rights has already been enforced by market participants.

JEL-Classification: D23, D74, K42

Keywords: Drug-dealing game, property rights, violence, peaceful equilibrium

ANPEC area: Microeconomics, Quantitative Methods and Finance

Resumo Estuda-se neste artigo uma situação na qual um acordo entre criminosos, lembrando estabelecimento de direitos de propriedade, pode emergir em mercados de drogas ilícitas. A *abordagem de desenho de mecanismo* é usada no principal resultado do artigo para mostrar que uma mudança dentro do sistema prisional (de um ambiente competitivo para a hegemonia de um grupo de criminosos) muda o Equilíbrio de Nash Perfeito em Subjogos (ENPS) vigente no mercado de droga ilícita fora da prisão, de um estado de guerra para a paz entre traficantes. Especificamente, é demonstrado que o grupo hegemônico *deseja* e *é capaz de promover* um acordo de paz entre os traficantes fora da prisão. Isto contrasta com o ENPS vigente quando não há hegemonia dentro do sistema prisional, no qual a possibilidade de expulsar competidores do mercado motiva nível positivo de violência. A principal implicação testável desta teoria não é rejeitada pelos dados disponíveis para São Paulo. Em termos estatísticos, a correlação entre crimes violentos e tráfico de drogas é positivo antes da mudança dentro do sistema prisional e inexistente depois dela. Tal resultado é relevante para política pública, pois mostra que a legalização de atividades ilícitas lucrativas não terá o efeito esperado (redução na violência) se os direitos de propriedade já foram estabelecidos pelos participantes do mercado.

Classificação JEL: D23, D74, K42

Palavras-chave: Jogo de tráfico de drogas, direito de propriedade, violência, equilíbrio pacífico

Área ANPEC: Microeconomia, Métodos Quantitativos e Finanças

*We are grateful to Cláudio Lucinda, Fabio Gomes, Daniel Santos, João M.P. Mello, José H. Faro, Rodrigo Soares, Braz Camargo, Daniel Monte, and Ricardo Cavalcanti for helpful comments and suggestions, and to seminar participants at FEARP-USP, INSPER and EESP-FGV. All errors are our own.

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1 Introduction

In Alchian (2008), property right is defined as a socially enforced right to select uses of an economic good. Also, such right to choose among alternative uses allows the exchange for similar rights over other goods. Most important for our purposes, society enforces the right to sell the good by detecting, convicting and punishing those (other than the right's owner) trying to restrict or to perform such exchange.

In that sense, one can see illicit markets as those for which society has assigned the property right over the corresponding good to itself and has decided to not sell it.¹ Licit markets, on the other hand, can be seen as those for which society has assigned the property right to dealers and enforces it, for example, by forbidding the use of violence among them as a competition instrument.

The extent to which property rights are enforceable depends on society's ability to detect, convict and punish those (other than the right's owner) trying to restrict exchanges in licit markets and/or to perform exchanges in illicit markets. If society's ability is high enough, no trading takes place in illicit markets and no violence is performed in licit markets in order to restrict property rights. On the other hand, if society's ability is not high enough, trading occurs in illicit markets, and violence takes place in both licit and illicit markets as a competition instrument – an instrument to enforce property rights.

The most obvious feature determining society's ability to enforce property rights is trading profitability. For highly profitable markets, both restricting other's trading and promoting his own trade are worth taking the risk to be punished by society. More subtle features are also important to determine detection and conviction capacity. For example, in societies where the respect to a relevant amount of human rights² is required when convicting and punishing someone, police work in detecting and evidencing crimes is a sophisticated activity and state's power to punish criminals is *bounded*. If the police is not sufficiently able to produce evidence of guilty while preserving criminals' human rights, judicial system in such societies is not able to convict them. Even though conviction is achieved, society cannot make punishment arbitrarily high without violating criminals' human rights. As a result, *criminals assess bounded expected punishment*.

Such reasoning about profitability and boundness can be seen as fundamental for the standard economic model to the decision individuals make between legal and illegal activities (Becker, 1968). According to this approach, potential criminals decide going illegal if the expected profitability of the illegal activity is greater than the bounded expected punishment they are exposed to. Applied to our discussion about licit and illicit markets, this model shows that property rights are not fully enforceable in markets for which profitability is greater than expected punishment. We make this point for the illicit-markets case in section 2 by presenting a game intended to model an illicit-drug market and showing that both violence and trading take place if expected punishment is low and expected profitability is high.

A situation not considered in Alchian (2008)'s definition is the case property right emerges even without society's enforceability. This would require an agent, other than the society-sponsored state, to *be able* and to *desire* to enforce such rights. Our result in this paper is that such agent can be a group of criminals that becomes hegemonic inside prison system. Building on Lessing (2014)'s analysis, we argue that a change inside the prison system, from a competitive environment to the monopoly, endows the hegemonic group with the ability to distort punishments inside prison. This establishes a *channel of influence* over out-of-prison criminals that can be used to enforce property rights in illicit drug markets.³ In section 3, we show that trading without violence among dealers

¹For example, Demsetz (1967) describes state ownership as a situation in which “the state may exclude anyone from the use of a right...”.

²See Assembly (1948).

³Also, because this agent is not necessarily constrained by human rights concerns, its ability to convict and punish those detected violating property rights is much higher than the society's one.

(property rights) is enforced in the illicit market model presented in section 2 if the hegemonic prison gang has sufficiently high power to distort expected punishment inside the prison system.⁴

1.1 Closely related literature

Our model makes use of standard tools found on the *Economics of Conflict* literature⁵ to study the market for illicit drugs. The conflict among dealers is a zero sum game in which each player seeks to obtain some prize (drug profits) by investing some effort or resources (violence). For this matter, we heavily build on Burrus (1999)'s model of competition among drug dealers.

In studying how participants in the illicit markets can collude to sustain a peaceful equilibrium inside the *Economics of Conflict*'s framework, we are closely related to Castillo (2013). But, while the author justify the cooperative behavior among drug dealers resorting to the standard combination of high level of patience and infinite horizon, our result holds on a two-stage model sustained by the prison gangs' influence over out-of-prison criminals studied in Lessing (2014). Our simpler model allows us to study the cooperative behaviour using the *mechanism design approach*. That way, we are not only able to establish that the peaceful arrangement is a subgame-perfect Nash equilibrium, as Castillo (2013) proposes to do, but also that it is the best equilibrium for the game designer (in our case, the prison gang).

As in Burrus (1999), the prize from the conflict in our model is the control over retailer drug markets while in the Castillo (2013)'s model it is the control over smuggling routes. The first fits well for drug-consumer countries like Brazil (our motivating case described in subsection 1.2) and USA while in the latter, Castillo (2013) intends to model drug-producer countries like Colombia.⁶

At a more basic theoretical level, our interpretation of such collusive arrangement as the emergence of property rights without society enforcement is related to Caldara (2013)'s analysis on how property rights emerges from anarchy. Such a connection could be used to see prison gang as a primitive form of state inside the democratic state, an interpretation we do not pursue here since it is not necessary to our result.

1.2 Empirical content of the theory

We present our motivating case, the fall on violent crimes rate in São Paulo in the 2000's, in order to establish the empirical content of the theory to be presented in sections 2 and 3.

São Paulo (hereafter SP), the richest state in Brazil, has experienced a sharp change in crime rates in the recent past⁷. Figure 1(a) shows that SP's experience on murder rates is atypical for the Brazilian context. It presents annual data on homicide rates for the state of SP and for the five regions in the country, from 1996 to 2011. In this period, homicide rate in SP fell on average 6.28% per year, while the average rate among the remaining states grew on average 2.4% per year.

Therefore, the causes for such decline seems to rest on specific features that differentiate SP from other Brazilian states. Consistent with the theoretical framework to be presented in sections 2 and 3, we argue that two factors make SP's experience unique in Brazil: (i) imprisonment policy in SP, which has traditionally been stricter than the other states', has become even more aggressive

⁴An important feature of our result is that it does not require unbounded power to distort punishment.

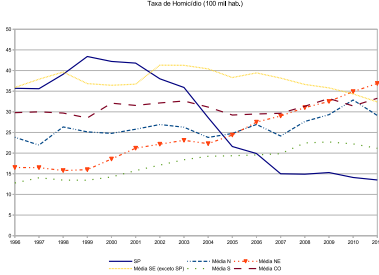
⁵See Garfinkel and Skaperdas (2007) for a comprehensive review on the economic theory of conflicts.

⁶For other theoretical works focused in drug-consumer nations see Reuter and Kleiman (1986) and Lee (1993). For drug-producer nations, see Grossman and Mejía (2008) and Poret (2002).

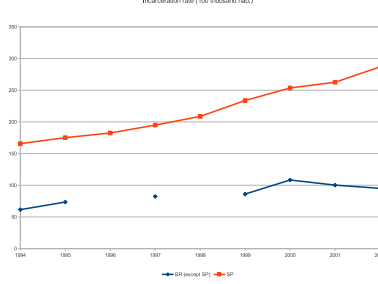
⁷Figure 5 in appendix B illustrates the big picture. Time-series for virtually all crimes in the figures have reversed trend at the beginning of the 2000's, after persistent growth in the 1990's. The most striking cases are violent crimes like murder, attempted murder, robbery followed by death, and vehicle robbery. Less violent crimes like theft, vehicle theft, and robbery (excluded vehicle robbery) have stopped increasing and remained stable in the 2000's. Finally, drug dealing registrations started growing at a higher rate from 2001 on. It grew on average 4% per year from the third quarter 1995 to the end of 2000 and 12% from the beginning of 2001 to the first quarter of 2014.

Figure 1: Some specific features to São Paulo’s experience

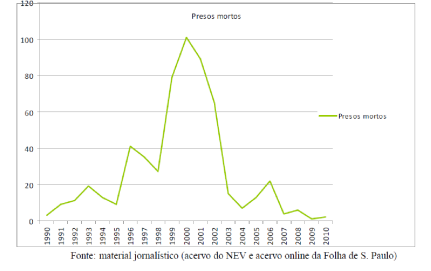
(a) Homicide rate - São Paulo and Brazilian regions



(b) Prison population rate – SP and Brazil (except SP)



(c) Murders in prison (SP, 1990-2010)



Source: (a) Waiselfisz (2006, 2013) (b) INFOPEN, SAP/SP and IBGE. (c) Dias (2011)

in the 1990’s and; (ii) a single group of criminals has consolidated control over prison life and has propagated it throughout the prison system⁸.

In section 4, we present an empirical analysis for the SP’s experience on the main testable implication of our theory: correlation between violent crimes (murder) and drug dealing changes from a positive level before the channel of influence (from inside to outside prison system) is established to no correlation after that. Specifically, we estimate the following relation between murder rate (h) and drug dealing rate (d), taking into account the channel of influence (c) from inside prison:

$$h = \delta_0 + \delta_1 c + \delta_2 d + \delta_3 c \cdot d + \theta \cdot X + \varepsilon \quad (1)$$

where X is a vector of covariates. Our theory predicts that before the channel ($c = 0$) correlation is positive ($\delta_2 > 0$) and that after the channel takes place ($c = 1$) correlation is inexistent ($\delta_2 + \delta_3 = 0$). As presented in table 1, our findings strongly support the first prediction and do not reject the second one at the level of significance of 5%.

2 A drug dealing game

We propose a model of drug dealing based on both dealers’ competition presented in Burrus (1999) and prison gangs’ influence over out-of-prison criminals studied in Lessing (2014). Two features in

⁸The first fact is illustrated in Figure 1(b), which displays the evolution for the incarceration rate⁹ in the 1990’s for SP and the remaining Brazilian states. It can be seen how singular SP’s imprisonment policy was. In 1994, incarceration rate was 2.7 times higher in SP. Moreover, it grew on average 3.49% per year in SP from 1994 to 2002, while it grew only 2.76% per year for the other states.

The second affirmative has been studied by sociology and political science literatures and publicized by the press. Dias (2011) presents a detailed description on the events that resulted in the consolidation and propagation of a group of criminals over the prison system in SP. By presenting similar case studies from Brazil, California, El Salvador, and Texas, Lessing (2014)’s analysis implies such situation is not specific to SP context. Figure 1(c) clearly illustrates how events inside prison the system follows closely trend reversion in crime rates (as presented in figure 5 in appendix B). Murders in prison (as a result of prisoners’ conflicts) has sharply increased in the 1990’s, but, starting in 2001, it fell at a rate even faster than it has increased.

Dias (2011)’s detailed presentation shows that most of such deaths resulted from conflicts among prison gangs during prisoners rebellions. Moreover, it is documented that by 2001 a single prison gang has emerged from these conflicts as the dominating organization inside the prison system. As a result, most of battles among prisoners ceased, as well as the associated murders.

Also, our theoretical framework brings consistency for two apparently unrelated evidence on the pattern of criminal activities.¹⁰ First, out-of-prison criminals are required to make monthly payments to the hegemonic prison gang, in what is known as ‘*mensalidades*’ (Dias, 2011, p. 230). Second, prison gang’s rules (laws) are enforced fast and effectively (though not necessarily respecting basic human rights) in what is known in Brazil as “*Tribunal do Crime*”, something similar to a court where prison gangs punish those not complying with its rules (Dias, 2011; Feltran, 2010).

this market are key for our analysis: (i) *dealing drugs is an illegal activity, and therefore, no dealer is able to legally enforce property rights over his selling post through the judicial system.* Instead, each of them protects their claimed properties and eventually violently attack their rivals.¹¹ Following Burrus (1999), we refer to these battles for selling posts as *turf wars*; and (ii) *dealers who are caught and arrested enter the prison system and can potentially be distorted by previously arrested criminals.* That establishes a (probabilistic) link between inside prison events and drug markets' functioning in that current prisoners could make treatment inside the prison system contingent on out-of-prison behavior. Following Lessing (2014), we refer to these group of current prisoners as the prison gang or PG.

2.1 The environment

There is a homogeneous drug, whose trading is illegal and for which (inverse) aggregate demand function is $P(Q)$. There are two dealers in the drug market, dealer 1 and dealer 2. It will be shown convenient to refer to dealer $j \in \{1, 2\}$ as D_j . Competition instrument is the violence to expel other dealer from the market. There is a police force to arrest those not complying with drug prohibition and/or committing violence acts.

The timing

The timing is given by two stages, as shown in Figure 2. First and second stages are denominated, respectively, turf war stage and trading stage. Police force acts twice. First, in between the turf war stage and the trading stage it arrests criminals for violence acts and excludes them from the drug market according to probability $\nu \in [0, 1]$, which we assume to be independent among criminals. Second, after the trading stage it arrests dealer $j \in \{1, 2\}$ for selling drugs and confiscates his revenues according to the probability $\rho \in [0, 1]$.¹²

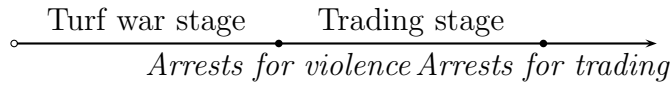


Figure 2: Timing of the two-stage game

The turf war stage:

In the first stage, each dealer chooses how much violence to implement in order to defend himself and/or to conquer monopoly power – over consumers and over the city's territory. The fight is summarized by a vector of violence amounts $V = (V_1, V_2) \in \mathbb{R}_+^2$ and the winner $w \in \{1, 2\}$. Actions (violence) in this stage are simultaneously chosen and determine the probability distribution over the two possible results for turf war: D_j defeats his opponent under probability $S_j(V)$ and is expelled from the market and gets nothing with probability $S_k(V) = 1 - S_j(V)$, $k \neq j$.

With probability ν dealer $j \in \{1, 2\}$ is arrested, suffers punishment h_j for each unit of violence acts he has performed, and stays out of the market¹³. We assume the cost h_j is composed of a punishment common to all prisoners, h , and a specific one, β_j , by supposing that $h_j = \beta_j h$ for $\beta_j \geq 1$.¹⁴

¹¹Classical example is violence among alcohol dealers in USA during prohibition of alcohol in the 1920's.

¹²For richer formulation in which the probability to be arrested dealing drugs depends on the quantity sold, see Poret and T       (2006).

¹³This is the present value of costs associated to being in the jail. It includes the traditional opportunity cost in form of wages he could earn during his time in prison, but also legal expenses during his trial and family expenses to visit him at the prison. Also, it captures monetary value of expected welfare losses of being inside prison. For example, individuals inside prison might face higher probability of getting sick or being victim of aggressions, robbery, extortion or murder.

¹⁴One could also assume this is a cost for the dealer's organization as a reduced-form modeling of contract relation between organization and its employees. See Polo (1996) for a rich formulation to this agency problem.

The trading stage:

Suppose turf war has taken place. Winner dealer $j \in \{1, 2\}$, if not arrested, trade drugs under monopoly: D_j decides how much drug to sell, $q_j \in \mathbb{R}_+$. There is no cost in producing and supplying drugs¹⁵ and, therefore, profits equal revenues, $P(q_j)q_j$. The (inverse) aggregate demand is assumed to satisfy the properties in Assumption 1¹⁶.

Assumption 1 *The inverse demand function $P(\cdot)$ is twice differentiable and such that $P'(\cdot) < 0$, $0 < P(0) < \infty$ and $\forall x \geq 0$ ($P''(x)x + 2P'(x) < 0$).*

With probability ρ , dealer $j \in \{1, 2\}$ is arrested, have their profits confiscated and suffers punishment $d_j = \alpha_j d$ for each unit of drug sold, where $\alpha_j \geq 1$. This is again the present value of costs associated to being in the jail and is composed by common and specific factors, d and α_j .

The police and the expected payoffs

Just before being exposed to the second police intervention, the expected payoff the monopolist dealer gets after selling Q units of drug and facing punishment factor α is

$$\pi(Q, \alpha) \equiv (1 - \rho)P(Q)Q - \rho d \alpha Q. \quad (2)$$

Similarly, just before the first police intervention, the expected payoff dealer j gets for each (V, Q, α, β) is

$$U_j(V, Q, \alpha, \beta) \equiv (1 - \nu)S_j(V)\pi(Q, \alpha) - \nu h \beta V_j \quad (3)$$

The Contest Success Function

The relation between probabilities and violence efforts is based in Contest Success Function literature that followed Tullock (1980)'s rent-seeking model.¹⁷ In the simplest formulation, the one we assume here, relative success is stated as a function of the ratio of the respective resource commitments – in our case, violence effort:

$$\frac{S_j}{S_k} = \frac{V_j}{V_k}, \quad \text{if } V_k > 0. \quad (4)$$

If $V_k = 0$, we have $S_k = 0$ if $V_j > 0$ and $S_k = S_j$ if $V_j = 0$. Using (4) and the fact $S_1 + S_2 = 1$, we have the same *Contest Success Function*¹⁸ studied in Hirshleifer (1989) and Burrus (1999)¹⁹:

$$S_j(V) = \begin{cases} \frac{V_j}{V_1 + V_2}, & \text{if } (V_1, V_2) \neq (0, 0) \\ \frac{1}{2}, & \text{otherwise.} \end{cases}$$

¹⁵Because our motivating case is a drug-consumer country, we abstract from wholesale drug market.

¹⁶First property in Assumption 1 requires demand for drugs to be downward sloping. The second one says that there exists a finite and positive price above which demand for drugs is zero. The third requirement means that revenues are concave in Q . Burrus (1999) assumes that inverse demand function is linear, a special case of Assumption 1.

¹⁷As pointed out by Hirshleifer (1989), however, such formulation “... applies far beyond the rent-seeking context. Military combats, election campaigns, industrial struggles (strikes and lockouts), legal conflicts (lawsuits), and even rivalries among siblings or between spouses within the family all fall under this heading” (Hirshleifer, 1989, p. 101).

¹⁸Axiomatization for more general contest success function has been provided by Skaperdas (1996) and Clark and Riis (1998). For an overview on how such functions has been used in Economics, see Garfinkel and Skaperdas (2007).

¹⁹Actually, our drug dealing model is heavily based in Burrus (1999)'s model. We only make few modifications in his setup. First, we generalize the inverse demand function from his linear functional form to the Assumption 1. Second, although assuming the same contest success function, we follow Garfinkel and Skaperdas (2007) in interpreting S_j as the probability under which D_j defeats his opponent, while Burrus (1999) makes S_j the market share D_j conquer for sure. Third, and most important, we allow punishment inside prison system to be specific to each dealer.

Minor differences between our model and Burrus (1999) is that all prisons in his model take place after trading stage. In our setup, prisons for violence acts happens before trading stage. Also, we assume that profits are confiscated when dealer is arrested for drug dealing, while Burrus (1999) does not.

2.2 The subgame-perfect equilibrium

In order to compute the subgame-perfect equilibrium for this game, we must impose that dealer's strategies constitute a Nash equilibrium in every subgame. We do this computing player's strategies in a backwards induction fashion, computing stage outcomes from the last stage to the first one.

The trading equilibrium:

Equilibrium outcome in the trading equilibrium is trivial, since dealers always operate under monopoly. The optimal quantity and the implied optimal expected profits are given by $q_m(\alpha) \equiv \arg \max_{Q \geq 0} \pi(Q, \alpha)$ and $\pi_m(\alpha) \equiv \pi(q_m(\alpha), \alpha)$, which are invariant to the violence amounts chosen in the turf war, $V = (V_1, V_2)$, since the objective function maximized in the trading stage does not depend on V , as defined in (2).

Lemma 2 *Let $\bar{\rho}(\alpha) = \frac{P(0)}{P(0)+d\alpha} < 1$. Then, for each $\alpha \geq 1$, $q_m(\alpha)$ is uniquely determined by*

$$\frac{\partial \pi}{\partial Q}(Q, \alpha) \leq 0 \quad \text{and} \quad Q \frac{\partial \pi}{\partial Q}(Q, \alpha) = 0. \quad (5)$$

As a consequence, $q_m(\alpha) > 0$ and $\pi_m(\alpha) > 0$ if and only if $\rho < \bar{\rho}(\alpha)$.

Proof. First, observe that (5) is the first-order condition to the monopolist's optimization in the trading stage. From Assumption 1, we have $\frac{\partial^2 \pi}{\partial Q^2}(Q, \alpha) = (1 - \rho)[P''(Q)Q + 2P'(Q)] < 0$ and, therefore, objective function is strictly concave. It follows that (5) delivers the unique optimal solution. For $q_m(\alpha) > 0$, observe that $\frac{\partial \pi}{\partial Q}(0, \alpha)$ is strictly positive if and only if $\rho < \bar{\rho}(\alpha)$ since it equals $(1 - \rho)[P'(0) \cdot 0 + P(0)] - \rho d\alpha = (P(0) + \alpha d)(\bar{\rho}(\alpha) - \rho)$. ■

Lemma 2 shows that drug dealing under monopoly is profitable if society's ability to enforce property rights is not high enough. Also, it is made explicit how such ability depends on the ability to detect and convict those dealing drugs (ρ) and the magnitude of punishment (α).

The turf war equilibrium:

Taking as given the equilibrium payoffs in the last stage, $\pi_m(\alpha)$, from (3) and lemma 2, expected payoff is

$$(1 - \nu)S_j(V)\pi_m(\alpha_j) - \nu h\beta_j V_j. \quad (6)$$

For each conjecture V_k about his opponent choice, D_j chooses $V_j \geq 0$ in order to maximize (6).²⁰ If detection and conviction is sure ($\nu = 1$) or dealing drugs is not worth at all ($\pi_m(\alpha_j) = 0$), then property rights are enforced in equilibrium since no violence ($V_j = 0$) is optimal for each possible conjecture $V_k \geq 0$. The other case ($\nu < 1$ and $\pi_m(\alpha_j) > 0$) is presented in what follows in this subsection.

Lemma 3 *Suppose that $\nu < 1$ and $\pi_m(\alpha_j) > 0$ for all $j \in \{1, 2\}$. Then, there is no optimal solution under conjecture $V_k = 0$.²¹*

²⁰We highlight that under the standard contest success function we assume here, the decisions on violence amounts are strategic complements.

²¹Lemma 3 states that, if police work in arresting criminals for violence acts is not perfect and punishment inside prison system is not high enough to make drug dealing non-profitable for all dealers, then no violence ($V_j = 0$) is not a best response for the no-violence conjecture ($V_k = 0$). Therefore, it implies that if a turf war equilibrium exists in this situation, then it entails positive violence for some dealer. The only cases no violence is a possible equilibrium outcome are those where violence is not worth at all ($\nu = 1$ or $\pi_m(\alpha) = 0$).

The *economics* behind this result is that, absent property rights, the only punishment D_j gets choosing $V_j = \varepsilon > 0$, with $\varepsilon \rightarrow 0$, is $h\varepsilon$ under probability ν , whereas the expected reward $(1 - \nu)\pi_m(\alpha_j)$ is strictly positive and invariant to ε . On the other hand, when dealing drugs is not illicit and property rights holds, defeated dealer can resort to the judicial system to require a punishment H to his aggressor. If such a punishment is high enough and invariant to the aggression level, so that $H > (1 - \nu)\pi_m(1)$, then no violence becomes a best response to no violence.

Proof. Suppose the conjecture $V_k = 0$ and observe that for every $V_j > 0$, we have $S_j(0, 0) = \frac{1}{2} < 1 = S_j(V_j, 0)$. Therefore, by choosing $V_j = 0$, dealer j gets $(1 - \nu)\pi_m(\alpha_j)/2 - \nu h\beta_j \cdot 0 = (1 - \nu)\pi_m(\alpha_j)/2$, and, by choosing any $V_j > 0$ he gets $(1 - \nu)\pi_m(\alpha_j) - \nu h\beta_j V_j$. Therefore, any violence amount V_j such that $0 < V_j < (1 - \nu)\pi_m(\alpha_j)/2\nu h\beta_j$ is a response to $V_k = 0$ strictly better than $V_j = 0$. In addition, any violence amount $\varepsilon > 0$ is strictly worse than $\varepsilon/2$ as a reply to $V_k = 0$. ■

Now, consider the conjecture $V_k > 0$ still in the case $\nu < 1$ and $\pi_m(\alpha_j) > 0$ for each j . Then, objective function (6) is strictly concave in V_j . Therefore, first-order condition and constraint $V_j \geq 0$ imply the following D_j 's best response function:

$$V_j(V_k) = \begin{cases} 0 & \text{if } V_k > (1 - \nu)\pi_m(\alpha_j)/\nu h\beta_j \\ \sqrt{\frac{(1 - \nu)\pi_m(\alpha_j)}{\nu h\beta_j}} \sqrt{V_k} - V_k & \text{otherwise.} \end{cases} \quad (7)$$

Observe that no violence is optimal to D_j if opponent's violence (V_k) is sufficiently high. The cutoff violence beyond which violence is not worth, $(1 - \nu)\pi_m(\alpha_j)/\nu h\beta_j$, is lower when D_j 's expected monopoly profits are lower and/or expected punishment for violence acts is high. This shows that dealer k is always able to surely expel D_j from the market by increasing V_k beyond such cutoff. But, from Lemma 3 we know that this cannot constitute an equilibrium, since D_k has no optimal response to no-violence conjecture ($V_j = 0$) when $\pi_m(\alpha_1) > 0$, $\pi_m(\alpha_2) > 0$ and $\nu < 1$.

Lemma 4 *Suppose that $\nu < 1$ and $\pi_m(\alpha_j) > 0$ for all $j \in \{1, 2\}$. Then, turf war equilibrium, for given equilibrium payoffs in the trading stage, is*

$$V^* = (V_1^*, V_2^*) = \left(\frac{(1 - \nu)\pi_m(\alpha_1)}{\nu h\beta_1} \theta(\alpha, \beta), \frac{(1 - \nu)\pi_m(\alpha_2)}{\nu h\beta_2} \theta(\alpha, \beta) \right) \quad (8)$$

where $\theta(\alpha, \beta) = \frac{\beta_1 \beta_2 \pi_m(\alpha_1) \pi_m(\alpha_2)}{(\beta_1 \pi_m(\alpha_1) + \beta_2 \pi_m(\alpha_2))^2} \leq 1$. As a consequence, equilibrium payoffs are

$$U_j^*(\alpha, \beta) \equiv (1 - \nu)\pi_m(\alpha_j) \frac{\beta_k \pi_m(\alpha_j)}{\beta_j \pi_m(\alpha_k)} \theta(\alpha, \beta). \quad (9)$$

Proof. V_j^* is obtained by computing $V_j^* = V_j[V_k(V_j^*)]$, where $V_j(V_k)$ is defined in (7). ■

Remark 5 *As a conclusion, lemmas 3 and 4 have shown that when society's ability to enforce property rights is not high enough ($\nu < 1$ and $\rho < \min_i \bar{\rho}(\alpha_i)$), violence and trading will take place in illicit drug markets.*

3 Property rights in illicit markets

We now extend the model in section 2 to allow the punishment dealers get inside prison system when arrested, (α, β) , to be distorted by previously arrested criminals. We compare two situations, which are intended to represent the two different equilibria inside prison system illustrated in Figure 1(b). The first one assumes a competitive environment among prison gangs and refers to the situation prior to 2000. In this case, no prison gang is able to distort punishments ($\alpha_j = \beta_j = 1$ for all j), since prisoners are equally exposed to attacks and protection from the competing identical gangs. In the second situation, the period after 2000, a hegemonic prison gang has emerged and become able to distort punishments up to a limit $\lambda \geq 1$ ²².

²²Throughout this section, we assume that social choice process (whatever it is) has resulted in an ability to enforce property rights such that $\nu < 1$ and $\rho < \bar{\rho}(1)$. That way, trading and violence occur in equilibrium in the first situation, as implied by section 2.2. In what follows in this section, we study the second situation.

3.1 The hegemonic prison gang's problem

Suppose the hegemonic prison gang (hereafter PG) wants to maximize its revenues and is able to perfectly monitor outside-prison actions. We suppose PG has no access to any production function so that the only way it potentially can get revenues is by extorting/taxing outside-prison drug dealers. The instruments for convincing them to comply with such taxation are a perfect monitoring ability and distortions in (α_j, β_j) based on D_j 's outside-prison behavior. PG's power to distort inside-prison payoff is not unlimited: we require $\alpha_j \in [1, \lambda]$ and $\beta_j \in [1, \lambda]$ ²³.

Inspired on our motivating case described in section 1.2, we assume PG demands payments from dealers before turf war stage and communicates how dealers should behave outside prison with respect to violence amounts (v_1, v_2) and drug dealing (q_1, q_2) . In addition, PG *credible* promises to distort punishment inside prison (α, β) according to (a, b) . The following definition makes clear the objects to be chosen by PG when building its extortion mechanism.

Definition 6 *An extortion mechanism is $e = (t, v, q, a, b)$ such that*

- (i) $t \in \mathbb{R}^2$ specifies a payment t_j from each dealer $j \in \{1, 2\}$,
- (ii) $v : \mathbb{R}^2 \rightarrow \mathbb{R}^2$ specifies a vector of violence amounts $v_\tau = (v_{1\tau}, v_{2\tau})$ for each payment vector $\tau \in \mathbb{R}^2$,
- (iii) $b : \mathbb{R}^4 \rightarrow \mathbb{R}^2$ describes for each possible (τ, V) , the punishment factor $b_{j\tau}(V)$ dealer j gets inside the prison system when arrested for violence acts,
- (iv) $q : \mathbb{R}^4 \rightarrow \mathbb{R}^2$ specifies, for each possible (τ, V) , the quantity $q_{j\tau}(V)$ to be sold in the market when D_j is the only seller; and
- (v) $a : \mathbb{R}^6 \rightarrow \mathbb{R}^2$ specifies, for each possible (τ, V, Q) , the specific punishment $a_{j\tau}(V, Q)$ dealer j gets inside the prison system when arrested for dealing drugs.

Observe that (a, b) is allowed to depend on how dealers has behaved outside prison, since a mechanism specifies what dealers are supposed to do, and which expected punishment they are exposed to, for each possible contingency could emerge from the drug dealing activity. Most important, dealers' outside option is to stay out of drug markets. Once operating in the market, they are subject to promised punishments (a, b) .

When choosing the extortion mechanism, PG is restricted to mechanisms that are feasible²⁴.

Definition 7 *The extortion mechanism $e = (t, v, q, a, b)$ is feasible if for each $j \in \{1, 2\}$ (i) $t_j \geq 0$*

- (ii) $v_{j\tau} \geq 0$ for all $\tau \in \mathbb{R}_+^2$
- (iii) $b_{j\tau}(v) \in [1, \lambda]$, for all $(\tau, V) \in \mathbb{R}_+^4$
- (iv) $q_{j\tau}(V) \geq 0$ for all $(\tau, V) \in \mathbb{R}_+^4$
- (v) $a_{j\tau}(v, Q) \in [1, \lambda]$ for all $(\tau, V, Q) \in \mathbb{R}_+^6$

Having defined what a feasible mechanism is, we are now able to define expected payoffs for PG and (D_1, D_2) . PG is assumed to derive utility from the revenues extorted from dealers and, therefore, its payoff function is

$$W(e) = W(t, v, q, a, b) = t_1 + t_2. \quad (10)$$

If D_j expects the other dealer to completely comply with the extortion mechanism e , then its expected payoff when paying $\tau \geq 0$ and complying with the remaining recommendations in the mechanism is denoted $U_j^e(\tau)$ and equals $U_j[v_{\hat{t}}, q_{j\hat{t}}(v_{\hat{t}}), a_{j\hat{t}}(v_{\hat{t}}, q_{j\hat{t}}(v_{\hat{t}})), b_{j\hat{t}}(v_{\hat{t}})]$, where $\hat{t} = (\tau, t_k)$ and the function $U_j(\cdot)$ is defined in (3).

²³Accordingly, λ can be view as an indicator of how powerful PG is in distorting (α, β) . PG's power is inexistent when $\lambda = 1$ and gets unlimited when $\lambda \rightarrow \infty$.

²⁴Property (i) in definition 7 requires payments from dealers to PG to be nonnegative, i.e., PG is not able to make payments to outside dealers. Condition (ii) establishes that violence cannot be negative, which could be interpreted as dealers not being able to caress each other in a way that is relevant for their expected payoffs. Property (iii) and (v) says that PG's power to distort prisoners' payoffs is limited by λ , and condition (iv) requires the trading to be nonnegative.

In addition to feasibility, **PG**'s choice is required to be compatible with dealers' participation and dealer's incentives, as presented in the following definition.

Definition 8 *The extortion mechanism $e = (t, v, q, a, b)$ is said to be compatible with D_j 's participation if it is feasible and*

$$U_j^e(t_j) - t_j \geq 0. \quad (\text{PC})$$

Also, it is said to be incentive compatible for D_j if it is feasible and (t, v, q) is optimal for D_j in each possible contingency, i.e.,

$$\text{for each } (\tau, V) \in \mathbb{R}_+^4, \quad q_{j\tau}(V) \in \arg \max_{Q \geq 0} \pi(Q, a_{j\tau}(V, Q)); \quad (\text{IC}_q)$$

$$v_{j\tau} \text{ solves } \max_{x \geq 0} U_j \left((x, v_{k\tau}), q_{j\tau}(x, v_{k\tau}), a_\tau \left((x, v_{k\tau}), q_{j\tau}(x, v_{k\tau}) \right), b_\tau(x, v_{k\tau}) \right) \quad (\text{IC}_V)$$

$$\tau_j \in \arg \max_{t \geq 0} \{U_j^e(t_j) - t_j\} \quad (\text{IC}_\tau)$$

Finally, the mechanism is implementable if it is compatible with participation and with the incentive for all dealers.

We are now able to define what is an optimal extortion mechanism for the prison gang.

Definition 9 *The mechanism $e^* = (t, v, q, a, b)$ is optimal for **PG** if it solves*

$$\max_e \{W(e) : (\text{PC}), (\text{IC}_q), (\text{IC}_V), \text{ and } (\text{IC}_\tau)\} \quad (\text{PGp})$$

In defining what a mechanism is, we have allowed **PG**'s choice to lie in a quite general space. This is intended to provide robustness to our no-violence result. Having that said, we show in subsection 3.2 that the optimal mechanism is quite simple: it promises the minimum punishment in the equilibrium path ($\alpha = \beta = 1$) and the worse treatment inside prison after any deviation from recommendations ($\alpha = \beta = \lambda$). Also, trading is always monopoly quantities $q_m(\alpha)$.

Remark 10 *Problem (PGp) is always feasible, since **PG** is always able to implement the subgame-perfect equilibrium described in section 2.2. It is enough to recommend punishments a and b invariant to history, the violence amounts presented in lemma 4, and no payments from drug dealers.*

3.2 Property rights' optimality and enforceability

In what follows, we provide a quite simple necessary and sufficient condition for the no-violence agreement among criminals (*property rights enforceability*) to be the optimal extortion mechanism for **PG**, i.e., to solve (PGp). Remarks 11 and 14 present properties the optimal extortion mechanism satisfy, respectively, out-of-equilibrium path and in the equilibrium path.

Remark 11 ***PG** chooses the harshest possible punishment after deviations from the extortion mechanism.*

Lemmas 12 and 13 establishes such result.

We first observe that at the optimal solution we have $a_{j\tau}(V, Q) = \lambda$ for $Q \neq q_{j\tau}(V)$, i.e., **PG** chooses the harshest feasible punishment for dealers not complying with its recommendation for trading after an arbitrary history (τ, V) with turf-war winner $w = j$. In order to see this is the case, observe that when $Q \neq q_{j\tau}(V)$, we have $a_\tau(V, Q)$ affecting (PGp) only through constraint (IC_q) . Also, (IC_q) can be rewritten as

$$\pi \left(q_{j\tau}(V), a_{j\tau} \left(V, q_{j\tau}(V) \right) \right) \geq \sup_{x \in \mathbb{R}_+ \setminus \{q_{j\tau}(V)\}} \pi(x, a_{j\tau}(V, x)) \quad (11)$$

for each $(j, \tau, V) \in \{1, 2\} \times \mathbb{R}_+^4$. But from definition (2), we know that $\pi(x, \alpha)$ is decreasing in α and, therefore, $\pi(x, a_{j\tau}(V, x)) \geq \pi(x, \lambda)$ for all feasible punishment $a_{j\tau}(V, x) \in [1, \lambda]$. As a consequence, we can take $\alpha_{j\tau}(V, x) = \lambda$ for all $x \neq q_{j\tau}(V)$ in order to minimize the right hand side (rhs) of inequality (11), since in doing so we relax (IC_q) without changing any other object in (PGp) . Since $\sup_{x \in \mathbb{R}_+ \setminus \{q_{j\tau}(V)\}} \pi(x, \lambda) = \pi_m(\lambda)$, we have established the following result:

Lemma 12 *Constraint (IC_q) can be replaced in problem (PGp) without loss of generality by constraints $a_{j\tau}(V, x) = \lambda$ for $x \neq q_{j\tau}(V)$ and*

$$\pi\left(q_{j\tau}(V), a_{j\tau}\left(V, q_{j\tau}(V)\right)\right) \geq \pi_m(\lambda), \quad \forall (j, \tau, V) \in \{1, 2\} \times \mathbb{R}_+^4. \quad (IC'_q)$$

Next, it is optimal to set $a_{j\tau}(V, q_{j\tau}(V)) = b_{j\tau}(V) = \lambda$ for $V \neq v_\tau$, i.e., PG chooses the harshest feasible punishments if someone refuses to comply with its recommendation for violence after history τ . As a consequence, constraint (IC'_q) for $V \neq v_\tau$ becomes $\pi(q_{j\tau}(V), \lambda) \geq \pi_m(\lambda)$ and binds since the unique implementable trading in this case is $q_{j\tau}(V) = q_m(\lambda)$, as implied by lemma 2. In order to see that the harshest punishment is optimal for $V \neq v_\tau$, observe that (IC_V) for D_j can be rewritten as

$$\sup_{0 \leq x \neq v_{j\tau}} U_j\left((x, v_{k\tau}), q_{j\tau}(x, v_{k\tau}), a_\tau\left[(x, v_{k\tau}), q_{j\tau}(x, v_{k\tau})\right], b_\tau(x, v_{k\tau})\right) U_j\left(v_\tau, q_{j\tau}(v_\tau), a_\tau[v_\tau, q_{j\tau}(v_\tau)], b_\tau(v_\tau)\right) \quad (12)$$

and that $q_{j\tau}(V)$ and $a_{j\tau}(V, q_{j\tau}(V))$, for $V \neq v_t$, affect problem (PGp) only through the left-hand side (lhs) of (IC'_q) and the lhs of (12). In particular, they affect (IC'_q) and (12) only through expected profits $\pi(q_{j\tau}(V), a_{j\tau}(V, q_{j\tau}(V)))$. Therefore, by minimizing the lhs of (IC'_q) until it binds, we relax (IC_V) without changing the objective function and the remaining constraints. Therefore, $a_{j\tau}(V, q_{j\tau}(V)) = \lambda$ and $q_{j\tau}(V) = q_m(\lambda)$. Finally, from definition (3), it is clear that the lhs of (12) is decreasing in $b_{j\tau}(V)$. Then, choosing the maximum feasible punishment $b_{j\tau}(V) = \lambda$ relax (IC_V) without changing the objective function and the remaining constraints. Thus, we have established the following property:

Lemma 13 *Constraints (IC'_q) and (IC_V) can be replaced in problem (PGp) without loss of generality by constraints $a_{j\tau}(V, q_{j\tau}(V)) = b_{j\tau}(V) = \lambda$ and $q_{j\tau}(V) = q_m(\lambda)$ for $V \neq v_\tau$, and for all $(j, \tau) \in \{1, 2\} \times \mathbb{R}_+^2$.*

$$\pi(q_{j\tau}(v_\tau), a_{j\tau}[v_\tau, q_{j\tau}(v_\tau)]) \geq \pi_m(\lambda), \quad (IC''_q)$$

$$U_j\left(v_\tau, q_{j\tau}(v_\tau), a_\tau[v_\tau, q_{j\tau}(v_\tau)], b_{j\tau}(v_\tau)\right) \geq \sup_{0 \leq x \neq v_\tau} U_j\left((x, v_{k\tau}), q_m(\lambda), \lambda, \lambda\right) \quad (IC'_V)$$

Remark 14 *PG minimizes punishment to cooperating dealers and maximizes their profits.*

We observe that for the equilibrium path (t, v_t) , it is optimal to maximize $\pi(q_{jt}(v_t), a_{jt}(v_t, q_{jt}(v_t)))$ and to minimize $b_{jt}(v_t)$, i.e., PG chooses for cooperating dealers the lightest punishment $b_{jt}(v_t) = a_{jt}(v_t, q_{jt}(v_t)) = 1$ and the most profitable trading $q_{jt}(v_t) = q_m(1)$. Such property comes from the fact that by maximizing equilibrium profits and minimizing equilibrium punishments, it is possible to relax constraints (PC) , (IC''_q) , (IC'_V) and (IC_τ) without changing objective function in (PGp) . To make this point clear, observe that (IC_τ) can be rewritten as

$$U_j^e(t_j) - t_j \geq \sup\{U_j^e(x) - x : 0 \leq x \neq t_j\}, \quad \forall j \in \{1, 2\}. \quad (13)$$

From definition of $U_j^e(t)$ and (3), it can be seen that $\pi(q_{jt}(v_t), a_{jt}[v_t, q_{jt}(v_t)])$ and $b_{jt}(v_t)$ appear only in the lhs of constraints (13), (PC) , (IC''_q) , and (IC'_V) . They are relaxed by minimizing punishment and maximizing profits in the equilibrium path.

As a consequence of remark 14, (IC''_q) slacks in the equilibrium path since it equals $\pi_m(1) \geq \pi_m(\lambda)$ and $\pi_m(\cdot)$ is decreasing. Also, the lhs of both (PC) and (13) becomes $U_j^e(t_j) - t_j = (1 - \nu)S_j(v_t)\pi_m(1) - \nu h v_{jt} - t_j$. We are now able to prove the following lemma:

Lemma 15 *Constraint (13) binds at the optimal solution e^* and, therefore,*

- *PG's objective function equals*

$$(1 - \nu)\pi_m(1) - \nu h(v_{1t} + v_{2t}) - \sum_{j=1,2} \sup_{0 \leq x_j \neq t_j} \{U_j^e(x_j) - x_j\}, \quad (14)$$

- *feasibility constraint $t_j \geq 0$ becomes*

$$(1 - \nu)S_j(v_t)\pi_m(1) - \nu h v_{jt} \geq \sup \{U_j^e(x) - x : 0 \leq x \neq t_j\}. \quad (15)$$

Proof. See appendix A. ■

Lemma 15 implies that PG's problem reduces to the choice of $(v_{j\tau}, q_{j\tau}(v_\tau))$ in \mathbb{R}_+^2 and $(a_{j\tau}[v_\tau, q_{j\tau}(v_\tau)], b_{j\tau}(v_\tau))$ in $[1, \lambda]^2$ for each $(j, \tau) \in \{1, 2\} \times \mathbb{R}_+^2$ in order to maximize (14) subject to (IC_q'') , (IC_V') , and feasibility constraint (15). Also, because (13) binds at the optimal solution, the properties established in lemmas 12 and 13 are not only without loss of generality, but also desired for PG. Most important, property (14) in lemma 15 shows that (if implementable) PG will optimally choose no violence in the equilibrium path ($v_{1t} = v_{2t} = 0$). The following proposition is our main result and establishes a (quite simple) sufficient and necessary condition for implementability of such no-violence agreement.

Proposition 16 *If $\nu < 1$ and $\pi_m(\alpha_j) > 0$ for all j , then the optimal extortion mechanism for PG features no violence in the equilibrium path ($v_t = (0, 0)$) if and only if*

$$\pi_m(1) \geq 2\pi_m(\lambda). \quad (16)$$

Proof. See appendix A. ■

Collusion sustainability

Our second result makes more transparent the conditions under which property rights can emerge after a prison gang becomes hegemonic inside the prison system. The purpose is to highlight the importance of the specific features to the São Paulo's experience discussed in subsection 1.2²⁵.

Corollary 17 *Suppose $\rho < \bar{\rho}(1)$ and $\nu < 1$. Then, optimal extortion mechanism for PG features no violence in the equilibrium path **if** either police effectiveness or PG's power inside prison system is high enough,*

$$\frac{\rho}{1 - \rho}\lambda \geq \frac{P(0)}{d} \quad (\text{POe})$$

and **only if** police work has some effectiveness ($\rho > 0$) and PG has some power inside the prison system ($\lambda > 1$).

Proof. From proposition 16, we know that $\nu < 1$ implies that no-violence in the equilibrium path is optimal if and only if $\pi_m(1) \geq 2\pi_m(\lambda)$, i.e., $\Gamma(\rho, \lambda) \equiv \max_{x \geq 0} [(1 - \rho)P(x)x - \rho dx] - 2 \max_{y \geq 0} [(1 - \rho)P(y)y - \rho dy] \geq 0$. For the necessity result, observe that $\Gamma(0, \lambda) = -\max_x P(x)x < 0$ for all $\lambda \geq 1$, and $\Gamma(\rho, 1) = -\pi_m(1) < 0$ for all $\rho \in [0, \bar{\rho})$. For the sufficiency result, remember that $\pi(Q, \alpha)$ is assumed strictly concave in Q and observe that its derivative at $Q = 0$ equals $(1 - \rho)P(0) - \rho d\alpha$. Then, using (5) we have $P(0) > \frac{\rho}{1 - \rho}d\alpha \Rightarrow \frac{\partial \pi}{\partial Q}(0, \alpha) > 0 \Rightarrow q_m(\alpha) > 0$. Also, $P(0) \leq \frac{\rho}{1 - \rho}d\alpha \Rightarrow \frac{\partial \pi}{\partial Q}(Q, \alpha) < 0, \forall Q > 0 \Rightarrow q_m(\alpha) = 0$. Now, observe that under (POe) and $\rho < \bar{\rho}$, we have $\frac{\rho}{1 - \rho}d < P(0) \leq \frac{\rho}{1 - \rho}d\lambda$ and, therefore, $q_m(1) > 0, q_m(\lambda) = 0$. As a conclusion, $\pi_m(1) > 0 = 2\pi_m(\lambda)$. ■

The sufficiency result holds because by increasing detention probability ρ and/or by increasing PG's power to punish deviators λ , the benefit in deviating from collusion is eliminated ($\pi_m(\lambda) \rightarrow 0$), while some benefit from cooperation is still available ($\pi_m(1) > 0$).

²⁵The intuition for the necessity result (which already appears in Lessing (2014)) is that traitor dealer could protect himself from prison gang punishment because he would never be arrested if $\rho = 0$, and that cooperation with PG would have no effect on imprisonment costs if $\lambda = 1$.

4 Empirical analysis: an application to São Paulo

São Paulo (or SP), the richest state in Brazil, has experienced a crime dynamics that is compatible with our theory results. First, the state experienced the strongest homicide rate decline in Brazil between 2001 and 2013 (30%). This evolution is remarkable different from other Brazilian states in the same period, making SP case an intriguing one.²⁶ But what factors could be driven this evolution? According to *Economics of Crime* literature, factors like unemployment and real wages could be responsible for this evolution. However, SP numbers in these two indicators reveals a pattern similar to ones found in other states. For example, while in SP, unemployment rate fall 4.8 percentage points between 2001 and 2012, similar to other states of Southeast region (4.3 p.p.). In terms of per capita GDP, SP growth between 20-01 and 2012 (2.6% per year) is smaller than neighbor states rates (3.1% per year). So, because wages and employment were increasing throughout the country in the 2000's, one can expect falling homicide rates as the rule in Brazil. However, Figure 1(a) shows that SP's experience is atypical for the Brazilian context. In the period shown in the figure, homicide rate in SP fell on average 6.28% per year, while the average among the remaining states grew on average 2.4% per year.²⁷

Therefore, the question on the causes for such decline must rest on specific features that differentiate SP from other Brazilian states. Consistent with the theoretical framework presented in sections 2 and 3, we argue that two factors makes SP's experience unique in Brazil: (i) imprisonment policy in SP, which has traditionally been stricter than the other states', has become even more aggressive in the 1990's and (ii) a single group of criminals has consolidated control over prison life and has propagated it throughout the prison system.

Facts (i) and (ii) have been illustrated in figures 1(a) and 1(b) in subsection 1.2, but fact (ii) deserves a more detailed discussion. The hegemonic gang inside SP's prison system is called *Primeiro Comando da Capital*, the SP counterpart of the PG in our model (hereafter SPPG). The origins of SPPG remounts to 1991, but the first known action of the group is its "formal" foundation as a gang during a rebellion in 1993. In this event, they impose their domination over a prison unity in the city of Taubaté (in SP), which was known by its strict discipline. One of the main claims in the rebellion (attended by the state government) was the transfer of the leaders in the rebellion to the largest Brazilian prison, *Casa de Detenção*, located in SP capital, São Paulo. The domination of Casa de Detenção was consolidated in 1995, when SPPG members killed other prison gang leaders in July, 23rd (Christino and Tognolli, 2017). SPPG expanded across prison unities in SP in a similar fashion, transfers of members to other facilities and subsequent rebellions in which opponents were killed (generally by decapitation).

The 1990's was a period of growing violence and strong instability inside the prison system (prison escapes, rebellions, and murders were frequent) and growth in the number of prisoners. According to Dias (2011), the murders inside the prison system presented in figure 1(b) for the period between 1996 and 2001 resulted from SPPG members eliminating rival gangs inside prison. The sharp decline in murders inside the prison system after 2001, on the other hand, is identified by Dias (2011) as evidence that SPPG becomes a hegemonic gang in SP prison system²⁸.

Another important piece of evidence about SPPG domination is the series of rebellions that took

²⁶Only two other states (Rio de Janeiro and Pernambuco) has experienced a fall in homicide rates in the period, but they were much smaller than SP's one.

²⁷Homicide rate's fall in figure 1(a) was driven by falling murder rates instead of manslaughter, as shown in graph ??(c). That way, we discard unintentional acts (like transit accidents, for example) as an explanation. Additionally, non-violent crimes do not show the same sharp decline in SP.

²⁸With the elimination of its main rivals, the consolidation of its domination and the conquest of hegemony, the Primeiro Comando da Capital achieved external and internal stability and promoted a complex accommodation of relations with the government, making it possible to completely reconfigure the social relations among the prisoners, constructing a new social order (...) characterized by a new balance of power in which physical violence ceases to be the central element of the domination relations(...) The reduction of the killings of prisoners is the effect of the consolidation of a power against which there are no longer rivals. So killing is not necessary anymore. (Dias, 2011)

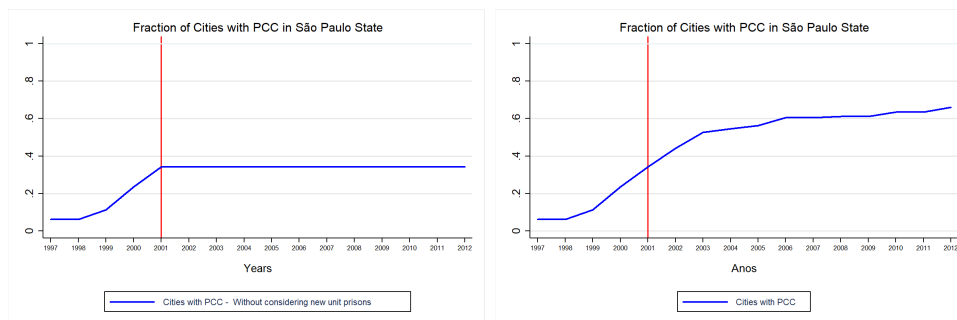
place in 2001 (hereafter “mega-rebellion”). They simultaneously happened in 29 out of 63 prison units and were the first public signal of **SPPG** domination of life matters inside the prison system. The mega-rebellion happened in February, 18th, during the tradicional visiting of relatives on Sundays. Up to this date, Sunday was a “sacred” day inside the prison according to an informal conduct code among prisoners that prohibited fights, rebellions, etc. This code was then broken with 25 thousand prisoners in 29 prisons rebelling against the transfer of some **SPPG** leaders from *Casa de Detenção*. Relatives of prisoners were taken as hostages and the rebellion started in all prisons in the same hour, denoting that they are communicating each other through cell phones.

The expansion of **SPPG** through the system between 2001 and 2006 took place with few episodes of violence inside prisons. The pattern was shaped by the construction of new prison facilities across the state. According to Dias (2011), as a strategy to difficult the type of coordination observed during the mega-rebellion in 2001, the new prison unities were built in smaller sizes and were located in a dispersed way across the state. The implied transfers of prisoners from old facilities to the new ones made it possible to **SPPG** to disseminate across the state without using violence against rival gangs. As a piece of evidence of such dissemination, **SPPG** organized in May (12nd) of 2006 riots in 74 out of 130 prisons. As the main demand, they protested against the transfer of its leader to a *maximum security* prison at Presidente Venceslau (a city in SP). Endowed with such power over the prison system, **SPPG** coordinated attacks outside the prison system at the same time of the rebellions: 55 police stations were attacked and 30 policemen were murdered.

Once we have this brief history of the origin, growth and hegemony of **SPPG**, we are able to precisely present our main empirical task. We investigate the impact of the emergence of this group inside SP’s prison system into the correlation between drug dealing and homicides. The objective is an empirical analysis for the SP’s experience on the main testable implication of our theory: correlation between violent crimes (homicides) and drug dealing changes from a positive level before the channel of influence is established (from inside to outside prison system) to no correlation after that.

The main challenge in such analysis is how to define a variable that incorporates the power of the **SPPG** inside the prison system. We capture the growing power of **SPPG** over time and space by studying every rebellion in SP since 1993 and identifying those that shows murders with decapitation as a clear evidence of **SPPG** domination. We assume that once **SPPG** dominates a prison inside a micro-region (a small set of neighbour municipalities), its influence cover every city in this micro-region. The figure 3(a) shows the fraction of cities dominated by **SPPG** according to this variable.

Figure 3: Fraction of cities with **SPPG**’s influence



As it is possible to see, after 2001, there is an stability in the number of cities over **SPPG** domination. However, after this period, there is also new prisons created. So, as a robustness check, we construct an alternative **SPPG** variable assuming that all new prisons opened after 2001 born already dominated by **SPPG** (and, consequently, all cities in its micro-region). With this variable, the configuration of proportion of cities dominated by **SPPG** is in Figure 3(b).

As a strong evidence that our strategy in constructing **SPPG** variable is trustworthy, it leads to the identification as a dominated prison of 25 out of 29 prisons that participated in the “2001 mega-

rebellion”. Two of these four prisons were created only two years before the mega-rebellion, what can explain the fact that we do not attribute it to SPPG domination up to 2001.

Data and Econometric Model

In order to investigate the relationship between drug traffic and homicides before and after SPPG in municipalities, we estimate the following model:

$$Homicide_{it} = \delta_0 + \delta_1 SPPG_{it} + \delta_2 Drug_{it} + \delta_3 SPPG * Drug_{it} + \theta X + \psi_t + \eta_i + \varepsilon_{it} \quad (17)$$

where $Homicide_{it}$ is the intentional homicide rate (per 100 thousands inhabitants) of the municipality i in year t ; $SPPG_{it}$ is a dummy variable indicating the year from which the municipality i becomes influenced by SPPG. $Drug_{it}$ is the drug traffic rate (occurrences per 100 thousands inhabitants) in municipality i in year t ; X is a matrix of control variables (formal sector wages Gini index; population density and urbanization rate); ψ_t is a set of year dummies; η_i is a set of municipality dummies and ε_{it} is an error term.

We have a panel data of municipalities of SP, encompassing the period between 1997 and 2006. This period is characterized by the growth and posterior fall of homicides in SP, as well as is the period of growth and consolidation of SPPG in the incarceration system.

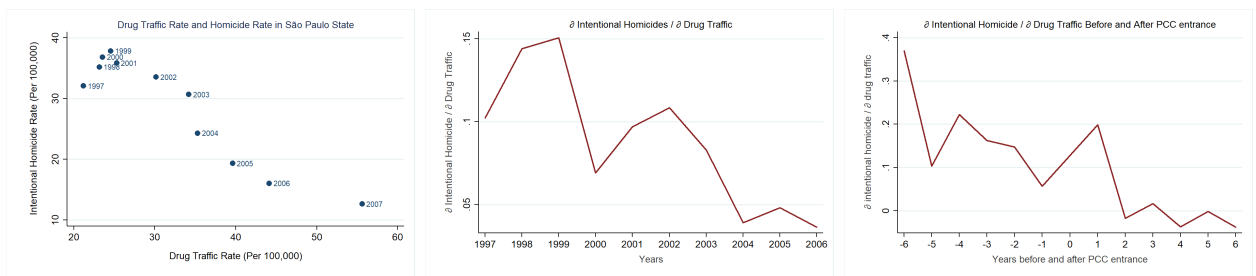
Clearly, the estimation of (17) is biased by fixed effects, because homicides and drug traffic are simultaneously determined and drug traffic is subject to measurement error. In order to handle this problem, we use an instrumental variable approach. In particular, we use two variables as instruments for drug traffic. The first one is the number of people covered by cell phones in the micro-region. We have information about the exact date of the installation of the first cell phone operator in each municipality of SP state. There is variation both in time and space in this variable and the period that we are considering encompass exactly the beginning of cell phone adoption in Brazil. The idea is that cell phone is an exogenous innovation that facilitates SPPG organization and reduces the risk of drug traffic activity. On the other hand, there is no plausible reason to think that cell phone adoption can be related to homicide rates except by drug traffic rates. The other instrument is the formal sector median wage of the municipality. The idea is that richer cities exhibit a more profitable drug market, leading to higher drug traffic but these aspect if unrelated to ε_{it} .

Descriptive Statistics

São Paulo has 645 municipalities, but in our paper we excluded those in microregions that do not have a prison unit. This is because the way we construct SPPG variable it cannot take a value 1 for cities in microregions without prison units and our sample ends with 439 cities.

Figure 4(a) shows the scatterplot of drug traffic and homicides in our sample over time. We can see that while there is a important decrease in homicide rate, the drug traffic has an opposite movement. But this aggregate figure do not precisely show that the correlation of drug traffic and homicide has declined with the growth of SPPG power. We then estimate the OLS model below in order to compute the correlation of these two crimes over time. The results are reported in 4(b).

Figure 4: Relation between drug dealing and homicides



$$Homicide_{it} = \alpha_0 + \alpha_1 Drug_{it} + \sum_{1996}^{2007} \delta_t \gamma_t + \sum_{1996}^{2007} \delta_t * Drug_{it} * \Theta_t + \varepsilon_{it} \quad (18)$$

Figure 4(b) shows that the correlation falls overtime. It is a reasonable pathway, considering that in 2001 SPPG dominated a large number of cities. So it is expected a fall in correlation after that. However, as we stated before, the SPPG entrance was heterogeneous in space and time. So, we estimate the following equation by OLS, relating the timing of entrance of SPPG in the city (lagged up to 6 years and forward 6 years for each city).

$$Homicide_{it} = \alpha_0 + \alpha_1 Drug_{it} + \sum_{j=-6}^6 SPPG_{ij} \gamma_j + \sum_{j=-6}^6 SPPG_{ij} * Drug_{it} * \Theta_j + \varepsilon_{it} \quad (19)$$

The results are reported in Figure 4(c) and show that before SPPG entrance, the correlation between homicides and traffic was positive and two years after SPPG entrance in the municipality, there is no more correlation among the crimes, a stylized fact in line with the predictions of our theory.

Results

We present the estimation results of equation (17) in table 1²⁹.

Table 1: Econometric estimations of equation (17)

	FE	IV-FE	FE	IV-FE
Drug*SPPG	-0.0006 (0.0484)	-1.216*** (0.278)	0.038 (0.036)	-1.536*** (0.430)
Drug	0.016 (0.043)	2.013** (0.828)	-0.015 (0.034)	2.831*** (0.954)
Gini	-0.814*** (0.179)	0.126 (0.577)	-0.782*** (0.171)	0.345 (0.673)
SPPG	0.117 (1.950)	36.58*** (8.12)	-4.643 (1.790)	48.96*** (12.18)
Population Density	-0.026*** (0.007)	-0.029* (0.015)	-0.024*** (0.005)	-0.039** (0.016)
Urbanization Rate	0.649*** (0.165)	0.098 (0.583)	0.493*** (0.169)	0.370 (0.543)
Year Dummies	Yes	Yes	Yes	Yes
P-value $\delta_1 + \delta_2 = 0$	0.434	0.074	0.190	0.299
N	4873	4873	4873	4873

The second stage result indicates the importance to consider the IV approach. The coefficients of drug dealing is positive in both IV estimations (supporting our theory implication). Before SPPG influence in the city, an increase in drug dealing in 1 case per 100.000 inhabitants is associated with a 2.0 to 2.8 increase in intentional homicide rate. After the SPPG enters the city, these relationship is strongly attenuated (-1.2 to -1.5). Testing the null hypothesis that the sum of these coefficients are equal to zero (our second theoretical prediction) leads to not reject the equality of these coefficients at 5% level in all cases, but in one estimation, we reject the null at 10%.

Our results shows that after SPPG enters in a city, there is a fall in the correlation between homicides and drug dealing, even after taking into count other regressors, time and cities specific effects and the endogeneity of drug dealing and homicides.

²⁹The dependent variable is the intentional homicide rate (per 100 thousand inhabitants). In the first two columns, the SPPG variable considers that prisons created after 2001 "born" dominated by SPPG. The last two columns do not consider new prisons after 2001 in the variable definition. All models are estimated with cluster of micro-regions, because SPPG variable is aggregated at this level. In columns 2 and 4 the instruments used are the number of people in the micror-region that lives in an area covered by cell phones and the median wage in the formal labor market. Data covered 443 cities in the period between 1997 and 2007.

5 Final remarks

We have provided a new channel through which property rights can emerge in illicit drug markets. Instead of resorting to infinite horizon and high patience, as Castillo (2013) proposes to do, we extend the two stage game in Burrus (1999) to show that the channel of influence studied by Lessing (2014), from inside to outside the prison system, makes reasonable to expect turf wars to cease after a prison gang becomes hegemonic inside prison system. Such expectation is shown reasonable using the mechanism design approach. Specifically, the hegemonic group of prisoners is shown to *desire* and to *be able to promote* the collusive agreement among dealers under which no violence is performed.

It is worth emphasizing that features in our model to illicit drug markets does not include some most commonly expected reasons for the peaceful arrangement to be attractive to drug dealing. Players do not spend productive resources in the conflict since there is no resource cost for violence acts. Violence effort affects only the probability distribution over turf war results, implying no losses from dead personnel or destruction. Also, demand for drugs and police work are invariant to violence levels and prison gang power to distort punishments is bounded. This property reinforces our argument for reasonability in predicting property rights to take place, since they do take place in our model even without the features just mentioned

We have argued for empirical content to our theory by presenting our motivating case, the fall on violent crimes rate in SP in the 2000's. The data strongly support the first theoretical prediction (correlation between drug dealing and murders is positive before SPPG) and do not reject the second (correlation is inexistent after SPPG) one at the level of significance of 5%.

More than having conclusive evidence on our theory for the changes in the pattern on crime rates, the strength of our reasoning comes from bringing consistence for apparently unrelated pieces of information, such as falling rates of violent crimes both inside and outside the prison system, increasing drug dealing in general, the existence of parallel Justice System (*Tribunal do Crime*), and monthly payments from outside to inside-prison-system criminals (*Mensalidades*).

For the discussion about public policies against violence, our theoretical framework weakens reasoning for drug legalization. Economists' argument for drug legalization as a way to fight violent crimes would have no effect if property rights have already been enforced in illicit drug markets.

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A Proofs

Proof of Lemma 15. We first establish that if (13) and (IC'_V) are satisfied, then (PC) holds. In effect, observe that the rhs of (IC'_V) is nonnegative for all τ , since D_j can always get nonnegative payoff by choosing no violence: $\sup_{0 \leq x \neq v_{j\tau}} U_j((x, v_{k\tau}), q_m(\lambda), \lambda, \lambda) \geq U_j((0, v_{k\tau}), q_m(\lambda), \lambda, \lambda) \geq (1 - \nu)S_j(0, v_{k\tau})\pi_m(\lambda) \geq 0$. Therefore, the lhs of (IC'_V) is also nonnegative. In particular, (IC'_V) for $\tau = (0, t_k)$ implies $U_j^e(0) \geq 0$. It follows that, if (13) and (IC'_V) hold, then (PC) is satisfied since $U_j^e(t_j) - t_j \geq \sup_{0 \leq x \neq t_j} (U_j^e(x) - x) \geq U_j^e(0) - 0 \geq 0$, where the first inequality comes from (13) and the second one has been just established.

Now, suppose that the optimal extortion mechanism $e = (t, v, q, a, b)$ features (13) slacking for at least one dealer $j \in \{1, 2\}$, i.e.,

$$(1 - \nu)S_j(v_t)\pi_m(1) - \nu h v_{jt} - t_j > \sup_x \{U_j^e(x) - x : 0 \leq x \neq t_j\}. \quad (20)$$

Then, consider an alternative extortion mechanism $\hat{e} = (\hat{t}, \hat{v}, \hat{q}, \hat{a}, \hat{b})$ that requires payments $\hat{t} = (t_j + \varepsilon, t_k)$ for $\varepsilon > 0$ and prescribes

$$(\hat{v}_\tau, \hat{q}_\tau(V), \hat{a}_\tau(V, Q), \hat{b}_\tau(V)) = \begin{cases} (v_t, q_t(V), a_t(V, Q), b_t(V)), & \text{if } \tau = \hat{t} \\ (v_{\hat{t}}, q_{\hat{t}}(V), a_{\hat{t}}(V, Q), b_{\hat{t}}(V)), & \text{if } \tau = t \\ (v_\tau, q_\tau(V), a_\tau(V, Q), b_\tau(V)), & \text{otherwise.} \end{cases}$$

That way, we assure that $U_j^{\hat{e}}(\hat{t}_j) = U_j^e(t_j)$, $U_j^{\hat{e}}(t_j) = U_j^e(\hat{t}_j)$, and $U_j^{\hat{e}}(\tau_j) = U_j^e(\tau_j)$ for all $\tau \notin \{t, \hat{t}\}$.

Since PG's objective function is strictly increasing in extortion payments, mechanism \hat{e} is strictly better than e . Also, because constraints (IC''_q) and (IC'_V) are satisfied by e , they also hold under \hat{e} since both mechanisms share the same violence and trading recommendations. For \hat{e} to be shown implementable, it remains to verify that (13) is satisfied under \hat{e} . First,

$$\begin{aligned} \sup_x \{U_j^{\hat{e}}(x) - x : 0 \leq x \neq \hat{t}_j\} &= \max \left\{ U_j^{\hat{e}}(t_j) - t_j, \sup_{0 \leq x \notin \{\hat{t}_j, t_j\}} \{U_j^{\hat{e}}(x) - x\} \right\} = \max \left\{ U_j^e(\hat{t}_j) - t_j, \sup_{0 \leq x \notin \{\hat{t}_j, t_j\}} \{U_j^e(x) - x\} \right\} \\ &\geq \max \left\{ U_j^e(\hat{t}_j) - \hat{t}_j, \sup_{0 \leq x \notin \{\hat{t}_j, t_j\}} \{U_j^e(x) - x\} \right\} = \sup_x \{U_j^e(x) - x : 0 \leq x \neq t_j\} \end{aligned} \quad (21)$$

where the second equality comes from $U_j^{\hat{e}}(t_j) = U_j^e(\hat{t}_j)$, and $U_j^{\hat{e}}(\tau_j) = U_j^e(\tau_j)$ for all $\tau \notin \{t, \hat{t}\}$.

If (21) holds equality, then from (20) we have that $\sup_x \{U_j^e(x) - x : 0 \leq x \neq \hat{t}_j\} = \sup_x \{U_j^e(x) - x : 0 \leq x \neq t_j\} < U_j^{\hat{e}}(\hat{t}_j) - \hat{t}_j$ holds for sufficiently low ε and (13) is satisfied by \hat{e} . On the other hand, if (21) holds with strictly inequality, then $U_j^{\hat{e}}(t_j) - t_j \geq \sup_{0 \leq x \notin \{\hat{t}_j, t_j\}} \{U_j^{\hat{e}}(x) - x\}$. In effect, suppose this is not the case. Then, $\sup_{0 \leq x \notin \{\hat{t}_j, t_j\}} \{U_j^{\hat{e}}(x) - x\} > U_j^{\hat{e}}(t_j) - t_j > U_j^e(\hat{t}_j) - \hat{t}_j$ and, therefore, $\sup_{0 \leq x \neq \hat{t}_j} \{U_j^{\hat{e}}(x) - x\} = \sup_{0 \leq x \notin \{\hat{t}_j, t_j\}} \{U_j^{\hat{e}}(x) - x\} = \sup_{0 \leq x \neq \hat{t}_j} \{U_j^e(x) - x\}$, a contradiction. It follows that, $\sup_{0 \leq x \neq \hat{t}_j} \{U_j^{\hat{e}}(x) - x\} = U_j^{\hat{e}}(t_j) - t_j$ and, therefore, $\sup_{0 \leq x \neq \hat{t}_j} \{U_j^{\hat{e}}(x) - x\} \leq U_j^{\hat{e}}(t_j) - t_j + \sup_{0 \leq x \neq t_j} \{U_j^e(x) - x\} - (U_j^e(\hat{t}_j) - \hat{t}_j) = \varepsilon + \sup_{0 \leq x \neq t_j} \{U_j^e(x) - x\}$, where the inequality comes from $\sup_{0 \leq x \neq t_j} \{U_j^e(x) - x\} \geq U_j^e(\hat{t}_j) - \hat{t}_j$, as implied by the last equality in (21). We conclude that $U_j^{\hat{e}}(\hat{t}_j) - \hat{t}_j - \sup_{0 \leq x \neq \hat{t}_j} \{U_j^{\hat{e}}(x) - x\} \geq U_j^{\hat{e}}(\hat{t}_j) - \hat{t}_j - (\varepsilon + \sup_{0 \leq x \neq t_j} \{U_j^e(x) - x\}) = U_j^e(t_j) - t_j - \sup_{0 \leq x \neq t_j} \{U_j^e(x) - x\} - 2\varepsilon > 0$ holds for sufficiently low ε when (20) holds. Again, we have shown that (13) is satisfied by \hat{e} . ■

Proof of proposition 16. Note that (IC'_V) is satisfied for $\tau = t$ and $v_t = (0, 0)$ if and only if $(1 - \nu)\frac{\pi_m(1)}{2} \geq \sup_{x > 0} \{(1 - \nu)S_j(x, 0)\pi_m(\lambda) - \nu h \lambda x\} = (1 - \nu)\pi_m(\lambda)$, which is equivalent condition (16) when $\nu < 1$. Because we have already established that (IC''_q) holds for $\tau = t$, it remains to show that both (15) and (IC''_q) for $\tau \neq t$ hold. Off-equilibrium (IC''_q) is trivially satisfied by $a_{j\tau}(v_\tau, q_{j\tau}(v_\tau)) = \lambda$ and $q_{j\tau}(v_\tau) = q_m(\lambda)$. Feasibility (15) holds because under no violence in the equilibrium path $U_j^e(t_j) = (1 - \nu)\frac{\pi_m(1)}{2} \geq (1 - \nu)\frac{\pi_m(\lambda)}{4} \geq \sup_{0 \leq x \neq \tau_j} (U_j^e(x) - x)$, where the last inequality comes from the following reasoning. We argue that off-equilibrium ($\tau \neq t$) recommendation $a_{j\tau}(v_\tau, q_{j\tau}(v_\tau)) = b_{j\tau}(v_\tau) = \lambda$, $q_{j\tau}(v_\tau) = q_m(\lambda)$ and $v_{j\tau} = V^*(\lambda) \equiv (1 - \nu)\pi_m(\lambda)/4\nu h \lambda$ is incentive compatible since it satisfy (IC''_q) and (IC'_V) with equality and (15) with strict inequality. In effect, (IC''_q) trivially binds and (IC'_V) binds because $\sup_{0 \leq x \neq v_{j\tau}} U_j([x, V^*(\lambda)], q_m(\lambda), \lambda, \lambda) = U_j([V^*(\lambda), V^*(\lambda)], q_m(\lambda), \lambda, \lambda) = (1 - \nu)\frac{\pi_m(\lambda)}{4}$, where the first equality is implied by lemma 4. For slacking feasibility, observe that the lhs in (15) under such recommendation satisfies $(1 - \nu)\frac{\pi_m(1)}{2} - \nu h(1 - \nu)\frac{\pi_m(\lambda)}{4\nu h} = (1 - \nu)\left[\frac{\pi_m(1)}{2} - \frac{\pi_m(\lambda)}{4}\right] > (1 - \nu)\frac{\pi_m(\lambda)}{4}$, while its rhs equals $\sup_{0 \leq x \neq t_j} (U_j([V^*(\lambda), V^*(\lambda)], q_m(\lambda), \lambda, \lambda) - x) = (1 - \nu)\frac{\pi_m(\lambda)}{4}$.

However, such off-equilibrium recommendation does not necessarily minimize $\sup \{U_j^e(x) - x : 0 \leq x \neq t_j\}$ as desired to increase PG's objective function (14) and to relax (15). In other words, the unique SPNE of the game

when treatment inside prison system is homogeneous among dealers and equal to λ is not necessarily the harshest implementable punishment after a deviation from t . Thus, the rhs of (15) satisfies

$$\sup_{0 \leq x \neq t_j} (U_j^e(x) - x) \leq \sup_{0 \leq x \neq t_j} (U_j([V^*(\lambda), V^*(\lambda)], q_m(\lambda), \lambda, \lambda) - x) = (1 - \nu) \frac{\pi_m(\lambda)}{4}. \quad \blacksquare$$

B Figures

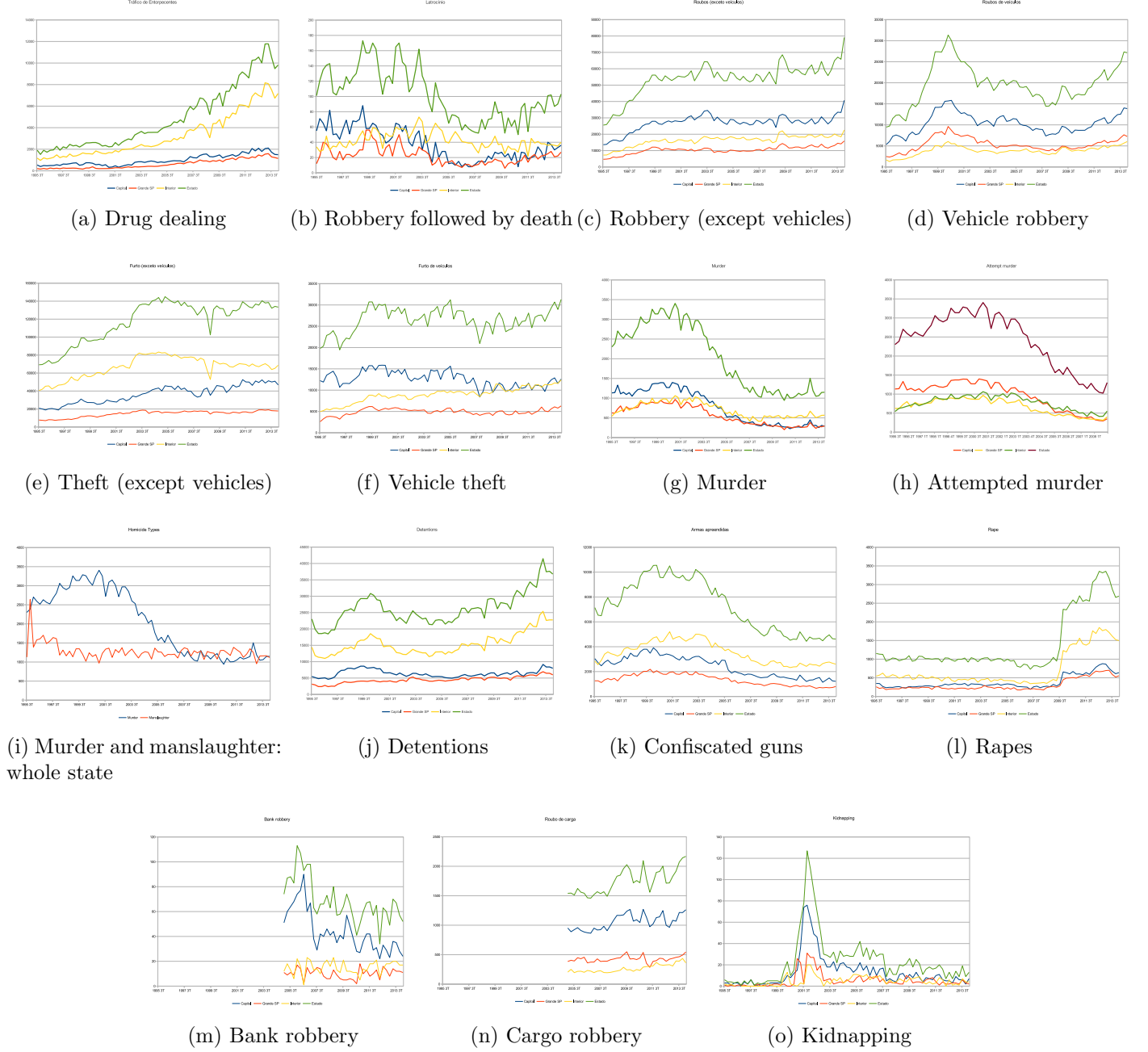


Figure 5: General overview on crime types (Source: SAP/SP)