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Optimal law enforcement and welfare in the presence of organized crime

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Jenni Pääkkönen

Optimal law enforcement and welfare
in the presence of organized crime



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Jenni Pääkkönen

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Tiivistelmä

Tässä keskustelualoitteessa tutkitaan Leviathan-tyyppisen hallituksen optimaalista lainvalvontaa silloin, kun maassa on järjestäytynyttä rikollisuutta. Hallitus on liian heikko estääkseen rikollisuuden nousun, joten se sallii mafian kerätä tuloa harmaasta taloudesta. Strategisen hallituksen ei kannata pyrkiä sulkemaan laitonta tuotantoa tai hankkiutua eroon mafiaa, vaan käyttää lainvalvontaa hankkiakseen lisätuloja harmaasta taloudesta. Samalla se voi nauttia kasvavasta veronpohjasta, kun mafian verottamat yritykset palaavat takaisin lailliselle sektorille. Mahdollisuus paeta harmaalle sektorille hyödyttää joitakin yrityksiä, vaikka mafian läsnäolo supistaa tätä hyötyä. Lainvalvonta on vahingollista sekä laillisille että laittomille yrityksille, joskin hallitus hyötyy siitä.

Asiasanat: järjestäytynyt rikollisuus, epävirallinen talous, verotus

Optimal Law Enforcement and Welfare in the Presence of Organized Crime*

Jenni Pääkkönen[†]

December 3, 2008

Abstract

This paper explores the optimal law enforcement strategy of a Leviathan government in the presence of organized crime. The government is considered too weak to prevent an upsurge in crime, so it allows the mafia to generate a positive payoff by extracting rents in the shadow economy. From a strategic standpoint, the government, if it has the possibility to monitor shadow production and fine offenders, may not want to shut down illegal production or kick out the mafia, but instead can use its policing activity to capture additional revenue through fines on illegal firm activities and an increased tax base when mafia-harassed firms return to the legal sector. The option of escaping into the shadow economy can benefit some firms, even when this utility is diluted by the presence of a mafia. Monitoring hurts both legal and illegal firms, while the government benefits.

JEL Classification: H26, H41, K42.

Key Words: Organized crime, shadow economy, taxation.

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1 Introduction

Numerous countries host crime groups (mafias, clans, triads, gangs, etc.) engaged in illegitimate activities such as drug dealing and extortion. Certain government actions (poorly designed tax policies, excessive or heavy-handed regulation, failures to deal with corruption, etc.) may distort the market equilibrium and offer incentives for entering the shadow economy or black market.¹ While this shifts the fiscal burden onto honest actors, legal firms often enjoy in return full access to goods and services produced by the government. On the other hand, the government can also create incentives for illegal production and rent-seeking opportunities for crime groups.² Along these lines, this paper considers the economic consequences of a Leviathan government that monitors and punishes underground production.

Numerous authors have considered the origins of organized crime. Anderson (1995) considers three examples of conditions that fostered mafia's emergence: the abdication of legitimate government power (Sicily), excessive bureaucratic power (former Soviet Union), and the potential of illegal markets (United States). Williams and Godson (2002) propose that a weak state, lacking in democracy or rule of law, offers fertile soil for the growth of organized crime. Skaperdas and Syropoulos (1995) model the emergence of gangs in the absence of control by the state. In the "grabbing-hand" model of Frye and Shleifer (1997), a weak state is characterized by predatory regulations, corrupt officials and a dysfunctional legal system. Although the emphasis has been on analyzing organized crime in the context of a weak state, Anderson and Bandiera (2000) point out that even strong, welfarist states like Japan host mafias. Moreover, they show that wherever a mafia has emerged, it has been difficult to root out.

Several studies take up government-mafia interaction, particularly in the context of law enforcement. Anderson and Bandiera (2000) study mafias as enforcement coalitions to protect property from predators.³ Grossman (1995) builds a model where public services enter in the production functions of legal and illegal firms alike, while the mafia produces a public good

¹Loyaza (1996) observes the size of the shadow economy is positively related to the tax burden and negatively to the quality of government institutions. Johnson and Kaufmann (2001) find the underground economy in transition economies has been driven mainly by excess regulation, corruption, a weak legal environment, and, to a lesser extent, by taxation.

²In the worst case, citizens and businessmen find themselves vulnerable to extortion from both the government and the mafia. See e.g. Johnson et al. (2000) and Los (2003).

³Italy's Cosa Nostra emerged as a defense mechanism for impoverished rural peasants against their landlords (e.g. Allum and Sands, 2004).

solely for illegal firms. As long as the government remains viable, the lot of the private producer improves as competition between the government and mafia increases the production of public goods. Alexeev et al. (2004) emphasize the role of the mafia as a provider of public goods. They show that when public goods are unimportant, the government actually benefits from the presence of the mafia as the mafia makes underground production costlier.

In Garoupa (2000) and Mehlum et al. (2003), crime groups are treated as rent-extracting, harmful organizations that do not offer public goods.⁴ Garoupa shows that as long as extortion constitutes a costless transfer from individuals to the criminal organization, extortion improves the social welfare by decreasing the incentive for harmful criminal offenses and allowing the government to reduce spending on law enforcement.⁵ In Mansour et al. (2006), gang structure is treated as endogenous; an increase in deterrence can lead to an increase in the number of competing criminal gangs and raise total illegal output.⁶ Lastly, Bowles and Garoupa (1997) propose a model in which the police and criminals collude. This model is then extended by Garoupa and Jellal (2007) to study corruption under asymmetric information. Kugler et al. (2005) also redo the analysis with imperfect competition. The findings of all these researchers contradict Becker's (1968) famous result on maximal fine and propose that increasing policing and sanctions beyond an optimal point can boost crime rates.

There is no consensus on the definition of social welfare with respect to individual ethics or crime, thereby some problems clearly emerge. For instance, if there is a conflict of interest between two or more members of society, how should the planner or the government treat and account their utilities? Surprisingly, this topic has received very little attention, while it has become standard to account both the costs and benefits from crime to the social welfare. Along these lines, some conclusions regards to the desirability of shadow economy and tax evasion are offered. Weiss (1976) concludes that a possibility of cheating on income taxes and random taxes in form of a probabilistic penalty might be socially useful. Alm (1985), however, suggests there are welfare costs associated with the underground economy due to inefficiency. Boadway

⁴Berkowitz and Li (2000) study a situation common in transition economies, whereby the government's tax rights are poorly defined. As a result, other agencies levy their own taxes on the same tax base. A standard tragedy-of-the-commons problem emerges in which the tax base is "over-grazed." The economy faces two equilibria according to the number of tax agencies with the implications for the share of illegal production, government's tax revenues, and production of public goods.

⁵Also Konrad and Skaperdas (1998) reach the same conclusions with a model in which the gang extorts from both legal and illegal enterprises.

⁶See Garoupa (2007) for similar analysis.

and Keen (1998) explore these arguments in the context of time-consistency, finding that by committing to relatively lax enforcement to facilitate evasion the government may be able to alleviate the welfare loss implied by its inability to commit to the tax rate. Kopczuk (2001) extended this framework to account for heterogeneity in avoidance behavior, arguing that tax avoidance may have redistributive benefits that should be considered as an additional policy instrument.

This paper seeks to shed light on the economic consequences of monitoring shadow activities. This issue is particularly relevant for Europe's transition economies, which are still experiencing major institutional reforms as they transform from command to market economies.⁷ A common pattern in European transition is that state enters the process enfeebled, resulting in a boom in illicit activities and organized crime (e.g. Johnson and Kaufmann, 2001). As the transition process advances, however, reform of the state apparatus and institutions forces decision-makers to seek optimal policies on taxation, provision of public goods, and the judiciary.⁸ Proponents of the "big bang" approach to transition reforms argued that, because the market economy offered such a huge benefits, countries could at first forego efforts at democratizing the political system and focus on reform of the economy. Nearly two decades into this process, however, we see transition economies where democratization has yet to materialize. Instead, we find Leviathan-type governments occupied by members of the *nomenklatura*, while numerous market and political failures persist.

The question that is completely new is how might policing the shadow economy of a rotten state affect the size of the shadow economy, taxation policy, and production of public goods. We evaluate how organized crime influences the government and firms. In particular, we consider who gains and who loses when illegal producers are monitored and punished.

We analyze the interaction of the government and the crime group in a context of a relatively stable state. As in Alexeev et al. (2004), we consider a sector of economy where a business can be conducted either legally or illegally, e.g. construction, trash-hauling, as well as harboring.

⁷Clearly, Europe's transition economies are not unique. Emerging economies such as Mexico and Columbia also suffer from this disease.

⁸Torgler (2003) notes that it has been difficult to find the right equilibrium of state activity in transition economies; there are strong traditions of state interventionism and bureaucracy without adequate protections for property rights. In the early years of transition, post-communist governments often extracted rents for their own use. Eventually, many governments evolved into constrained Leviathans, i.e. non-welfarist, revenue-maximizing states that produce a few public goods to keep people happy. See also Konford (2000).

The firm makes a choice between legal and illegal production in the presence of government and mafia rent-seeking.⁹ The Leviathan government is not concerned on the welfare of the citizens; instead it maximizes its own payoff. It produces public goods to which illegal firms have partial access.¹⁰ The crime group does not provide protection or anything else in exchange for the rent. We assume the government lacks adequate resources to fight organized crime, but can monitor illegal production. No collusion of government agents and criminals is allowed.

We first solve the model in the absence of the mafia as a benchmark. We then introduce the organized crime and explore both the static and the dynamic games. To compare our results with previous studies and name the winners and losers, we consider the game without monitoring.

The main results are the following. First, it is always the case that the revenue-maximizing government will monitor the shadow economy, with or without a mafia present. Second, a policy of monitoring supports government tax policy; tax rates are increased if the shadow sector expects punishment for tax evasion. Thereby, the government uses its power to monitor to extract more from the *formal* economy. The entry of the mafia increases the government's revenue since the exit option is now more expensive. By the same token, both legal and illegal firms are hurt by the entry of the mafia.

Results related to monitoring provide additional insights. The size of the shadow economy is independent of monitoring, because the government increases taxes when it monitors, while the public goods are unaffected. Moreover, legal and illegal firms alike benefit and in the absence of monitoring, while the government is the clear loser. The mafia goes completely unaffected by monitoring. From the normative point of view, whether the government should monitor shadow economy depends on whose benefits are emphasized.

The paper is structured as follows. Section 2 phrases the model and Section 3 presents the benchmark results absent organized crime. Section 4 introduces a crime group into a Cournot game and a Stackelberg game. Section 5 discusses the welfare effects of monitoring under the different assumptions. Section 6 concludes.

⁹Baumol (1990) views the history of productive, unproductive, and destructive entrepreneurship. Acemoglu (1995) models the allocation of talent in the presence of rent-seeking.

¹⁰Baumol (1995) comments that dynasties are typically established through violence; governments concerned with the welfare of citizens are historical rarities. See also La Porta et al. (1999).

2 The model

Assume a continuum of firms with the mass of one and that each firm produces one unit of output at the market price of one. Following Alexeev et al. (2004), a firm entering an industry faces a choice between legal or illegal production. The firm chooses its sector by comparing the potential payoffs or refrains from production if it cannot make the reservation profit 0. Although legal production is subject to tax t , the firm benefits from public goods g produced by the government. We write the payoff π_l of a legal firm as

$$\pi_l = (1 - t) + g. \quad (1)$$

An illegal firm, in contrast, pays rents r to the mafia.¹¹ The public goods are partially excludable and parameter b represents the factor of public goods enjoyed by the illegal firms $0 < b < 1$. An example of a public good denied from illegal firms would be contract enforcement. On the other hand, illegal firm clearly benefit from many public goods such as roads and other infrastructure. Illegal firm also face an exogenous penalty, $z < 1$, if their activities are discovered by government monitoring agents.¹² The probability of getting caught is p . Thus, payoff π_{ij} for the illegal firm may be described as

$$\pi_{ij} = (1 - r) + bg - pz - c_j, \quad (2)$$

where c_j is the cost of operating in shadow economy for firm j . By setting (1) equal to (2), we solve the threshold cost for going underground

$$\bar{c} = t + (b - 1)g - pz - r. \quad (3)$$

Firms with $c_j > \bar{c}$ enter the legal sector; the rest enter the illegal sector. The cost of operating in the shadow economy, c_j , can be viewed as the cost difference between legal and illegal production, where the negative values suggest that some firms benefit from going underground. Extra costs associated with illegal production include the lack of access to the formal credit and finance. Benefits may include freedom from accounting systems and operating licenses. Indeed, much of the bureaucratic burden facing legal firms is avoided by going underground. Whether

¹¹Here it is assumed that the rent is the only cost the firms face because of the mafia. It could well be that both legal and illegal firm are harmed by a cost, say, k , which would not affect the outcome as long as both types of firms must deal with it and the mafia draws no benefit from it.

¹²One way to see the role of p and g are to think of them as the institutions provided by the government.

the costs or benefits dominate depends on the skills of the entrepreneur, i.e. the sign of c_j . The cost is distributed uniformly between $[-x, x]$, where $x < 1$ illustrates the degree of the heterogeneity of entrepreneurs; the larger the value of x , the more heterogeneous community of entrepreneurs. The cumulative distribution function of c and the size of the shadow economy is

$$F(\bar{c}) = \frac{1}{2x} (\bar{c} + x), \quad (4)$$

where \bar{c} is defined by (3).

The government maximizes its profits that are the revenue from taxes and from fines minus the production of public goods and monitoring services. We simplify the model by assuming that collecting taxes involves no costs. We also assume that the fine is set by an independent court or the planner. Next, the government chooses t , g and p to maximize its payoff

$$G(t, g, p) = (1 - F(\bar{c}))t + F(\bar{c})pz - \frac{1}{2}g^2 - \frac{1}{2}p^2, \quad (5)$$

subject to the constraint that $\pi_l(\bar{c}) = k \geq 0$, i.e. the marginal firm will receive its reservation profits.¹³ In the equation (5), the first term is the tax revenue from the legal sector, the second term is expected income from fines from the illegal sector and the last two term are the cost of producing public goods and policing.

Similarly, the payoff for the mafia is defined as the income from rent-extracting minus costs of collecting the rent. In other words, the amount of rent the mafia can collect from illegal firms is self-limiting; the more the mafia want to extract rents, the higher the costs of rent-seeking. Thus, the mafia will seek to maximize its payoff with respect to r , i.e.

$$M(r) = F(\bar{c})r - \frac{1}{2}r^2. \quad (6)$$

The timing of these games is such that in a static game, the government and the mafia move simultaneously and are followed by the firms. In a dynamic game, the government moves first, then the mafia. Only after the mafia has moved do firms decide whether to move themselves.

In the present analysis, we focus on interior solutions and the comparability of results among different scenarios (a detailed description is given in Appendix A). To this end, we make certain restrictions on x and z . As stated, it is a reasonable intuition that the cost of operating underground and the penalty of discovery are both less than the income generated

¹³Here, all firms that choose to remain in the legal sector receive the same profit as the marginal firm. Those in the illegal sector obtain higher profits due to their entrepreneurial skills.

by illegal production. Obviously, rules governing legal production, i.e. $\pi_l(\bar{c}) > 0$, must exist in all these set-ups.

To make our three set-ups comparable and obtain interior solutions, we must identify the sub-set of $\{x, b, z\}$ where all these solutions exist. Assumption 1:

1. Assume $2x > -(b-1)$ and $z^2 < 1 - \frac{4x(1+x)+(1+2x)(b-1)}{8x(1+x)-(1+2x)(b-1)^2} \frac{(3+2x)}{(1+2x)}x$ are both true.

Equations (1) to (6) and Assumption 1 describe the full model, which includes shadow production, a mafia, and active monitoring by the government. First, however, we address our baseline scenario: a mafia-free economy.

3 The birth of shadow markets in the absence of a mafia

Obviously, if there is no shadow economy, firms have nowhere to go to escape the grabbing hand of the government. The government, in turn, has full power to determine the tax rate, what public goods it provides, and appropriate the profits of firms. Of course, if a firm is left with nothing, entrepreneurs have a strong incentive to start producing illegally.

First, we rewrite equation (2) as

$$\pi_{ij} = 1 + bg - pz - c_j.$$

The threshold cost for firms entering the shadow economy is obtained from the indifference $\pi_l = \pi_{ij}$, with the result that $\bar{c}_1 = t + (b-1)g - pz$, where subscript 1 indicates the game in the absence of the mafia, i.e. $r = 0$. Thus, the size of the shadow economy, i.e.

$$F(\bar{c}_1) = \frac{1}{2x} (\bar{c}_1 + x) = \frac{1}{2x} (t + (b-1)g - pz + x), \quad (7)$$

increases as taxation rises or public goods, penalties or monitoring are reduced. It is crucial here to acknowledge that there are indirect costs transmitted via changes in the size of the shadow economy in addition to the direct costs of producing public goods and monitoring.

The payoff for the government follows equation (5). Subject to $\pi_l(\bar{c}) \geq 0$, we optimize the Lagrangian with respect to the tax rate, public goods, and monitoring. The FOCs are

$$\begin{aligned} \frac{\partial G}{\partial t} &= 0 \iff \frac{\partial F(\bar{c}_1)}{\partial t} (pz - t) + (1 - F(\bar{c}_1)) + \lambda_t \cdot \frac{\partial \pi_l(\bar{c}_1)}{\partial t} = 0 \\ \frac{\partial G}{\partial g} &= 0 \iff \frac{\partial F(\bar{c}_1)}{\partial g} (pz - t) - g + \lambda_g \cdot \frac{\partial \pi_l(\bar{c}_1)}{\partial g} = 0 \\ \frac{\partial G}{\partial p} &= 0 \iff \frac{\partial F(\bar{c}_1)}{\partial p} (pz - t) - p + F(\bar{c}_1)z = 0, \end{aligned} \quad (8)$$

where $\lambda_{t,g}$ is the shadow price of legal profit at the margin wrt tax (public goods), and $\lambda_{t,g} > 0$ when $\pi_l(\bar{c}_1) = 0$ and $\lambda_{t,g} = 0$ otherwise. Since $\frac{\partial \pi_l(\bar{c}_1)}{\partial t} < 0$ and $\frac{\partial \pi_l(\bar{c}_1)}{\partial g} > 0$, we know that increasing the marginal firm's reservation profit will decrease the optimal tax and increase the amount of public goods. Operating under Assumption 1, i.e. $\lambda_{t,g} = 0$, we pose (8) the following propositions:

Proposition 1 *The government should strive to collect taxes at an optimum rate $t > 0$.*

Proposition 2 *Monitoring should always be part of an optimal policy from the government's standpoint.*

Proof. Since $0 < F(\bar{c}_1) < 1$, it must be that $\frac{\partial G}{\partial t} |_{t=0} = (1 - F(\bar{c}_1)) + \frac{\partial F(\bar{c}_1)}{\partial t} p z > 0$ for all non-negative p . Similarly, setting $p = 0$ gives $\frac{\partial G}{\partial p} |_{p=0} = -\frac{\partial F(\bar{c}_1)}{\partial p} t + F(\bar{c}_1) z > 0$. ■

The intuition is that the government does not incur direct costs from taxation even with indirect costs from an increase in the size of the shadow economy. Clearly, when t is small, benefits exceed the costs of taxation. Note also that when $p = g = 0$, the size of the shadow economy in equation (7) is never zero as long as $t \geq 0$. The intuition for the second result is that when p is small, income generated under a monitoring regime exceeds the costs of monitoring. Therefore, monitoring increases the payoff for the government. The optimal solution for the tax rate, the amount of public goods and the monitoring are

$$t_1 = \frac{-2x^2}{-4x + (b-1)^2} + z^2, \quad (9)$$

$$g_1 = \frac{x(b-1)}{-4x + (b-1)^2}, \quad (10)$$

$$p_1 = z. \quad (11)$$

We now analyze how exogenous variables affect the optimum, noting first that increases in b decrease both the tax rate and the amount of public goods. The intuition here is that when b , the benefit an illegal firm draws from public goods, increases, production in the shadow economy becomes more attractive. The government reacts by decreasing the production of public goods - which now hurts the illegal firm more than previously - to decrease the production costs. At the same time decreased taxation and makes operating in the legal economy more attractive. Indeed, the increased size of the legal sector may be enough to offset the effect of lost government income from an increased b .

Second, increases in the penalty z always increase the tax rate and monitoring, while having no effect on public goods. In particular, since $p_1 \cdot z$ is z^2 , the firm faces a penalty in one form or another, and that cost will not affect the choice of sector. This makes sense, since from (5) we observe that when the government is able to monitor, albeit the cost for the illegal firm is probabilistic, the government can collect at least some rent from all the firms in the economy. Setting the expected penalty as a minimum rent collected from all firms, while collecting something extra from legal firms, say a , the income for the government can now be rewritten as $(1 - F(\bar{c}))(pz + a) + F(\bar{c})pz = pz + (1 - F(\bar{c}))a$. Thus, income pz is always certain, while income related to a is uncertain. Moreover, the size of the shadow economy can be written as $\frac{1}{2x}(a + (b - 1)g + x)$, i.e. the effect of monitoring on the shadow economy is completely neutralized. Thereby, increases in the penalty z lead, one to one, to increases in monitoring, while the government neutralizes the effect of the expected penalty by increasing, one to one, the tax rate and leaving everything else unaffected.

Lastly, increases in the heterogeneity of the skills of entrepreneurs, x , decreases the amount of public goods and increase taxes. Monitoring remains unaffected. Thus, the most skilful entrepreneurs can make more profit operating in the shadow economy, while those less skilled benefit more from remaining in the legal sector. The overall productivity of the firms increases, allowing the government to grab more revenue. Although increasing the tax rate and decreasing the production of public goods drives some entrepreneurs to the illegal sector, the government collects more from individual firms remaining in the legal sector and enjoys lower costs for production of public goods.

Substituting the solutions to the payoff for legal firms gives a strictly positive result; the government can never extract all revenues of legal firms:

$$\pi_{l1} = 1 - z^2 + \frac{(b - 1) + 2x}{-4x + (b - 1)^2}x > 0. \quad (12)$$

Evaluating (12), we find the revenue of legal firm *decreases* when b rises. An increase in b decreases the amount of public goods and the tax rate, so the net effect on the legal firm's payoff is negative. Increases in penalty z *decrease* the revenue of the legal firm. Thus, we intuit that when the amount of public goods produced remains unchanged while the tax rate is increased with the penalty the net effect is to hurt the legal firm's profits.

Solving for this threshold, we obtain

$$\bar{c}_1 = \frac{-2x + (b - 1)^2}{-4x + (b - 1)^2}x.$$

Evaluating the threshold under Assumption 1, we find that $\bar{c}_1 < 0$ if $x < \frac{1}{2}(b-1)^2$, and positive otherwise. Since the penalty does not affect the threshold, we infer that the size of the shadow economy is also unaffected.

Proposition 3 *The size of the shadow economy is unaffected by monitoring.*

Firms with a cost of entering the shadow economy below \bar{c}_1 will choose illegal production. The size of the shadow economy is $0 < F(\bar{c}_1) < \frac{3}{4}$, i.e. the shadow economy must account for more than zero percent and less than 75 percent of total production. The size of the shadow economy decreases if the benefit from public goods decreases for firms in the illegal sector. The higher the excludability of public goods, the greater the incentive for firms to stay in the legal sector. Increases in x boost the size of the shadow economy, giving the most skillful entrepreneurs more opportunities in the shadow economy.

Solving for the government's payoff, we get

$$G_1 = \frac{1}{2} \left(z^2 + \frac{x^2}{4x - (b-1)^2} \right). \quad (13)$$

The benefit the illegal firm draws from public goods decreases government's payoff, while the governments' payoff is increased in the penalty. Clearly, the ability to monitor benefits the government in two ways, first there is a direct income from the shadow economy in form of fines and then there is an increased income from the legal sector, since it is able to increase the tax rate, while keeping the amount of public goods constant. It appears that the government's tax policy is backed up by monitoring.

4 The mafia arrives

We now assume the market is occupied by two authorities, both capable of extracting rents. The government has two unique features: it can produce public goods, and, as sole legal authority, can monitor the shadow economy. On the other hand, the government is too weak to control the mafia fully or eradicate it. The choice a firm faces under this scenario requires comparing equations (1) and (2). The threshold cost for going underground is determined, following equation (3), by the decisions of the government and the mafia. For example, a decrease in rent r , ceteris paribus, means more firms will find it profitable to operate underground. The size of the shadow economy is determined according to equation (4), and the government

chooses t , g , and p to maximize its payoff at equation (5). The mafia maximizes its payoff from equation (6) with regard to r .

Now the game can be played either as a Cournot competition, where the mafia and the government move simultaneously, or as dynamic game as Stackelberg game where one party moves first. While the Cournot game is simpler, the Stackelberg game seems closer to reality as there is a likely pattern whereby the legal authority emerges first and the mafia follows in reaction. To gain intuition let's first analyze Cournot.

4.1 Simultaneous moves

The payoffs for the government and for the mafia in the static game are presented by equations (5) and (6), now denoted by subscript 2. To solve for the tax rate, monitoring, public goods, and the rent, we attempt to identify the *best-response functions* for the government and the mafia. Optimizing G with respect to t, g , and p , results in the reaction functions for the government. Optimizing M with respect to r yields the reaction function for the mafia. From the FOCs of the government, we get

$$\begin{aligned}\frac{\partial G}{\partial t} &= \frac{\partial F(\bar{c}_2)}{\partial t} (pz - t) + (1 - F(\bar{c}_2)) \\ \frac{\partial G}{\partial g} &= \frac{\partial F(\bar{c}_2)}{\partial g} (pz - t) - g \\ \frac{\partial G}{\partial p} &= \frac{\partial F(\bar{c}_2)}{\partial p} (pz - t) + F(\bar{c}_2)z - p.\end{aligned}\tag{14}$$

Upon evaluation, we see Propositions (1) and (2) also apply in this set-up. The FOC for the mafia can be written as

$$\frac{\partial M}{\partial r} = \frac{\partial F(\bar{c}_2)}{\partial r} r + F(\bar{c}_2) - r = 0.\tag{15}$$

Equation (15) illustrates how the optimal rent depends on the existence and size of the shadow economy. As t , g and p are not directly present in (15), government policies can influence mafia decisions only through the impact of government actions on shadow economy.

Proposition 4 *When there is a shadow economy, the mafia should strive to collect rents.*

Proof. Evaluating the mafia's FOC at $r = 0$ gives $\frac{\partial M}{\partial r} |_{r=0} = F(\bar{c}_2) > 0$. ■

Proposition 4 states that collecting rents is predicated on the existence of a shadow economy. But as was shown in Proposition 2, it also makes sense for the government to monitor the shadow economy and try to extract rents when the activities of illegal firms are detected.

Solving the unknowns from these linear equations, we obtain

$$\begin{aligned}
t_2 &= \frac{2x^2(3+2x)}{2x(3+4x) - (1+2x)(b-1)^2} + z^2, \\
g_2 &= -\frac{(3+2x)(b-1)x}{2x(3+4x) - (1+2x)(b-1)^2}, \\
p_2 &= z, \\
r_2 &= -\frac{2x((b-1)^2 - 3x)}{2x(3+4x) - (1+2x)(b-1)^2}.
\end{aligned} \tag{16}$$

These results are quite similar to the situation in a mafia-free system. Evaluating the mafia's rent according to Assumption 1, we find it increases in line with benefit gained from partaking in public goods. Thus, the mafia "taxes" the increased benefit enjoyed by the illegal firm. Note that mafia's rent is clearly below the tax rate, even in the absence of monitoring. Using the solutions in (16), we find the size of the shadow economy is diminished by the presence of a mafia (see Appendix B).

Comparing our results for with and without a mafia, we find that the optimal amounts of monitoring are the same. Evaluating the optimal tax and amount of public goods shows that $t_2 > t_1$ and that $g_2 > g_1$, i.e. while the emergence of a mafia allows the government to raise taxes, it also requires to increase production of public goods. As the government is unable to extract all profits of legal firms, we reach

Proposition 5 *Both legal and illegal firms are worse off once a mafia enters the shadow economy.*

Proof. See Appendix B. ■

The arrival of the mafia places the government in a stronger position vis-à-vis legal firms; it can increase taxes more than it increases public goods. While these changes create an incentive to go underground, the entry of a mafia increases costs of illegal production. The overall incentive to produce underground is reduced, so illegal firms are generally worse off after the arrival of a mafia, thereby the size of the shadow economy decreases with the entry of a mafia. Moreover, the government's profits exceed those of the mafia, because the government has multiple means to grab firms revenues.¹⁴ Particularly, the government is free to collect rents from firms in both sectors, while the mafia can only collect rents from firms in the illegal

¹⁴It is straightforward to establish $G_2 > M_2$ is true under Assumption 1.

sector. Since the rent or the size of the shadow economy is not determined by the fine, the mafia's payoff is unaffected by it.

Proposition 6 *The arrival of a mafia increases the government's payoff.*

Proof. See Appendix B. ■

Surprisingly, the government is better off when the mafia enters the shadow economy. As soon as the shadow economy has emerged, the government has no incentive to get rid of mafia!

In the presence of shadow production and a mafia, government policies have the similar effects on government income as before. Taxation incurs no direct costs, but there are indirect costs through the changes in the size of the shadow economy and the tax base. From a strategic standpoint, it is wise for the government to neutralize the effect of monitoring by setting it as a base tax. What is different from the previous set-up is that rent paid to the mafia benefits the government indirectly, since the rent has the tendency to decrease the size of the shadow economy and thereby boost tax income. Thus, the government's tax policy is supported by both its own monitoring and mafia rent-seeking.

4.2 Stackelberg game

We now make the natural assumption that legal authority emerges before the mafia arrives. Here, we analyze a dynamic game where the government is the Stackelberg-leader and the mafia is the follower. The threshold cost and the payoffs follow equations (3) - (6). Hence, optimizing for the follower yields the FOC for the mafia as in equation (15) or in terms of the *best-response function*

$$r = \frac{1}{2(1+x)} (t + (b-1)g - pz + x), \quad (17)$$

where increases in taxation have a tendency to increase rents, while the increases in public goods or monitoring tends to decrease rents. Optimizing the government's payoff with regard to t , g , p , and simplifying gives

$$\begin{aligned} \frac{\partial G}{\partial t} &= \left(\frac{\partial F(\bar{c}_3)}{\partial t} + \frac{\partial F(\bar{c}_3)}{\partial r} \cdot \frac{\partial r}{\partial t} \right) (pz - t) + (1 - F(\bar{c}_3)) \\ \frac{\partial G}{\partial g} &= \left(\frac{\partial F(\bar{c}_3)}{\partial g} + \frac{\partial F(\bar{c}_3)}{\partial r} \cdot \frac{\partial r}{\partial g} \right) (pz - t) - g \\ \frac{\partial G}{\partial p} &= \left(\frac{\partial F(\bar{c}_3)}{\partial p} + \frac{\partial F(\bar{c}_3)}{\partial r} \cdot \frac{\partial r}{\partial p} \right) (pz - t) + F(\bar{c}_3)z - p. \end{aligned} \quad (18)$$

Comparing optimality conditions in (18) to those in (14) shows that the optimal solutions for t , g , p , are probably different from those in Cournot. Then the solutions for unknowns are

$$\begin{aligned}
t_3 &= \frac{4x^2(1+x)(3+2x)}{(1+2x)\left(8x(1+x) - (1+2x)(b-1)^2\right)} + z^2, \\
g_3 &= -\frac{(3+2x)(b-1)x}{8x(1+x) - (1+2x)(b-1)^2}, \\
p_3 &= z, \\
r_3 &= \frac{2x}{(1+2x)} \frac{x(6x+5) - (1+2x)(b-1)^2}{8x(1+x) - (1+2x)(b-1)^2}.
\end{aligned} \tag{19}$$

Evaluating these under Assumption 1 and comparing the solutions to those for the Cournot competition, we see that $t_3 > t_2$, $g_2 > g_3$, $p_2 = p_3$, and $r_3 > r_2$ (see Appendix B). In the Stackelberg game, the government can increase the tax rate and simultaneously decrease the amount of public goods it provides. Monitoring is constant from one set-up to another as it serves as a minimal rent the government will collect from all firms. The government's actions increase the size of the shadow economy, which forces the mafia to raise its rents, i.e. $r = \left(1 + \frac{\partial F(\bar{c}_3)}{\partial r} \frac{r}{F(\bar{c}_3)}\right) F(\bar{c}_3)$. The size of the shadow economy is larger here than in the Cournot competition (see Appendix B).

Proposition 7 *Both legal and illegal firms are worse off in the Stackelberg game than in the Cournot competition.*

Proof. Since $g_3 - t_3 < g_2 - t_2 < 0$, legal firms must be worse off in the Stackelberg game than in the Cournot game. Since $p_2 = p_3$ and $r_3 > r_2$, illegal firms must also be worse off in the Stackelberg game. ■

Since both the legal and illegal firms lose more in the Stackelberg game, it would seem that the government, the mafia, or both, benefit. Is it possible, however, for both the government and the mafia to increase their income in the Stackelberg game?

Regarding the mafia's income, we know that since the size of the shadow economy is larger in the Stackelberg game than in the Cournot competition, rents are also higher than under Cournot, which implies that mafia income increases. On the other hand, the mafia's costs for collecting rents also go up, so the overall impact is ambiguous. For the government, we know that the amount of monitoring does not change, yet the increased size of the shadow economy income necessarily means greater income from penalties. Since the amount of public goods the government produces is lower, the costs of producing public goods also decreases. Lastly, the

tax rate rises, while the legal economy shrinks, so again the overall effect of the higher tax rate on the payoff is ambiguous. Comparing $G_3 > G_2$ and $M_3 > M_2$ under Assumption 1, however, shows that

Proposition 8 *Both the government and the mafia gain more income in the Stackelberg game than in the Cournot competition.*

Proof. See Appendix B. ■

In the Stackelberg game, the government and mafia increase their payoffs. Of course, we expect here that the first-mover will capitalize on this advantage and try to grab as much as possible – behavior that results in a larger shadow economy. Since the mafia sets rents according to the size of the shadow economy, it will surely raise its rents as long as the costs for doing so do not impair the overall benefits. From a firm’s point of view, the best scenario is where the government and mafia compete neck and neck; when there is a leader and a follower authority, firms lose.

5 Welfare and enforcement

Sections 2 to 4 hold powerful implications about the government’s ability to monitor shadow production. Since the literature largely neglect the monitoring of shadow production, and hence, optimal law enforcement, let us briefly consider the welfare effects of monitoring and enforcement.

There is no consensus on the definition of social welfare with respect to individual ethics or crime. Harsanyi (1955) suggests that a public policy aimed at satisfying the preferences of the individual members of society, the welfare function should take the form of a sum of individual utilities. The interpretation in the context of shadow economy is that where there is no conflict of interest between two or more members of society and no negative externalities associated with shadow production, then it must be fully accounted for in the sum of utilities and may, in fact, increase welfare.¹⁵ Clearly there are limits to this approach, as in the context of crime the conflicting interests will emerge. While this controversy has received little attention, it has become standard to account the costs and the benefits of a harmful act to the social welfare.

¹⁵Davidson et al. (2007) propose that, depending on the attributes of the goods supplied on the black market, the black market may actually increase welfare.

Considering the above insights, we calculate the ordinary social welfare defined as a sum of the utilities of firms and the authorities, i.e. the sum of costs and benefits associated with the production of goods and services in the economy. Taxes and the income from monitoring and rents are transfers, so they cancel out. The costs of producing them, however, are apparent. As a result, we formulate the welfare in the presence of a mafia as

$$W = (1 - F(\bar{c})) (1 + g) + F(\bar{c}) (1 + bg) - \int_{-x}^{\bar{c}} \frac{c}{2x} dc - \frac{1}{2}g^2 - \frac{1}{2}p^2 - \frac{1}{2}r^2. \quad (20)$$

We assume that the planner is now responsible for maximizing the welfare after all the players have made their decisions. If we let the planner choose the penalty, then there is only one sensible course of action:

Corollary 9 *Under a Leviathan government, the planner should set the penalty to zero.*

The intuition is that since there are only costs and no benefits associated with monitoring, the planner would not punish the offenders. This is because we treat shadow production here as a victimless crime, i.e. nobody gets hurt from it. As there are net benefits associated with illegal production, i.e. $c_i < 0$ for some firms, it is always welfare-increasing to have shadow economy in the absence of the externalities.

To evaluate the effect of monitoring on the optimum, we set $p = 0$ and redo the analysis in Sections 2 and 4. Comparing the results with and without monitoring, simply evaluating the FOCs proves that in all these set-ups $t > t^{p=0}$ and $g^{p=0} = g$, i.e. the tax collected is greater with monitoring as long as public goods production remains unaffected. This means that a legal firm is better off when the government does not monitor the shadow economy, i.e. $1 - t^{p=0} + g^{p=0} > 1 - t + g$ for all these set-ups. The incentive to engage in shadow production, in turn, must increase, since there is no cost for getting caught. The mafia's rent, however, is unaltered by monitoring. Also the size of shadow economy is unaffected by monitoring. Then it must be the case that both types of firms are hurt by monitoring, the government benefits from monitoring, while the mafia is unaffected by it.

Corollary 10 *Monitoring strengthens the government's position over firms, but does not affect the mafia's position. Both legal and illegal firms are worse off under a monitoring regime.*

Thus, governments that are not concerned with the welfare of their citizens should be stripped of their power to monitor illegal producers, since monitoring acts as a rent-extracting

tool comparable to bribery. Correspondingly, if court system cares for the position of legal firms, it should set $z = 0$.

6 Conclusions

In this paper, we studied the interactions of a government, an organized crime group (mafia), and firms operating in the legal and illegal sectors of the economy. Our results highlight the role of the public policy in shaping production, as the government creates the incentives for illegal production. Mafias flourish when there is an opportunity to extract rents on production in the shadow economy.

The ability of the government to monitor illegal activities does not alter the size of the shadow economy. When the government monitors illegal production, it collects higher taxes thereby in the margin the incentives for firms are unaffected. Moreover, the government has the authority to punish offenders, so it has an extra tool for extracting fines from firms. Thus, the government eliminates the fiscal externality of tax evasion by collecting fines. This means that a revenue-maximizing government should always monitor the shadow economy, even though the mafia is completely unaffected by monitoring. Indeed, even in the situation where there is no collusion between the government and the mafia, monitoring benefits both groups.

When discussing the winners and losers in these different set-ups, we note that, in a mafia-free environment, legal firms benefit from shifting to the shadow economy to increase profits. In a Cournot competition, however, the appearance of a mafia on the scene changes the outcome as the profitability is lowered for both legal and illegal firms. When the mafia collects rents in the shadow economy, illegal firms seek to abandon the shadow economy. At the same time, however, the government can increase the tax rate and reduce production of public goods, thereby hurting both legal and illegal firms. In a Stackelberg game, the profits of both legal and illegal firms decrease, while the payoffs for the government and the mafia increase. Again, the appearance of a mafia is harmful to firms in both the legal and illegal sector. Meanwhile, the government benefits as the mafia's activities indirectly support its policies. If the fine is viewed as a hidden tax or a bribe, then corrupted governments should be stripped of the right to punish offenders.

The study has raises several interesting questions that suggest lines of further study, including a rich vein of potential work in the area of social welfare. Indeed, what would the

equilibrium look like and the social welfare consequences be if the government and mafia colluded? Would a more welfare-oriented government be more successful in limiting the size of the shadow economy?

A Restrictions for interior solutions

We evaluate the restrictions necessary to have an interior solution in each game under three existence rules: legal and illegal production must exist, and the government must produce public goods. Although these restrictions seem to change from one set to another, there is a sub-set of the restrictions where all games have an interior solution. The restrictions are obtained from first-order conditions.

In the first two set-ups for the existence of the shadow economy, it must be that $3x > (b-1)^2$. For the third, it is required that $(b-1)^2 < \frac{x(6x+5)}{(1+2x)}$, where the first one is binding. For the existence of the public goods in the first set-up, it is required that $4x > (b-1)^2$. This is not binding, however, when $F(c) > 0$. In the second set-up, the existence of public goods requires that $(b-1)^2 < \frac{2x(3+4x)}{(1+2x)}$. In the third set-up, the existence of public goods requires that $(b-1)^2 < \frac{8x(x+1)}{(1+2x)}$. The second and the third requirements are not binding whenever $3x > (b-1)^2$. Thereby $3x > (b-1)^2$ must be binding to have interior solutions for public goods and for the shadow economy in all these set-ups.

Lastly, there must be existence rules for legal production, i.e. $\pi_l(\bar{c}_j) > 0$. Evaluating these existence rules is a bit more complicated, since they set limits on the penalty. First, we evaluate these under an assumption that $3x > (b-1)^2$. Then we write Assumption A1 for our benchmark game without the mafia, Assumption A2 for the Cournot game and Assumption A3 for the Stackelberg game. To have $\pi_l(\bar{c}_j) > 0$ requires that

$$\text{A1 } z_1^2 < 1 - \frac{(b-1)+2x}{4x-(b-1)^2}x. \text{ For } z < 1, \text{ it must be that } 2x > -(b-1).$$

$$\text{A2 } z_2^2 < 1 - \frac{(2x+(b-1))(3+2x)}{2x(3+4x)-(1+2x)(b-1)^2}x. \text{ For } z < 1, \text{ it must be that } 2x > -(b-1).$$

$$\text{A3 } z_3^2 < 1 - \frac{4x(1+x)+(1+2x)(b-1)}{8x(1+x)-(1+2x)(b-1)^2} \frac{(3+2x)}{(1+2x)}x. \text{ For } z < 1, \text{ it must be that } \frac{4x(1+x)}{1+2x} > -(b-1).$$

Since $\frac{4x(1+x)}{1+2x} > 2x$, $2x > (1-b)$ is more restrictive. Comparing the existence rules for the legal sector, we find that for all x, b the requirement $z_3^2 < 1 - \frac{4x(1+x)+(1+2x)(b-1)}{8x(1+x)-(1+2x)(b-1)^2} \frac{(3+2x)}{(1+2x)}x$ is the most restrictive, and hence binding. We have been able to identify two rules that provide the existence of an interior solution. Therefore we write Assumption 1 as

1. Assume $2x > -(b-1)$ and $z^2 < 1 - \frac{4x(1+x)+(1+2x)(b-1)}{8x(1+x)-(1+2x)(b-1)^2} \frac{(3+2x)}{(1+2x)}x$ are both true.

B Proofs

B.1 Cournot vs. No mafia

To show that the tax in a Cournot competition is higher than the tax in the benchmark, and setting $t_2 > t_1$

$$\begin{aligned}
\frac{2x^2(3+2x)}{2x(3+4x) - (1+2x)(b-1)^2} + z^2 &> \frac{-2x^2}{-4x + (b-1)^2} + z^2 \\
\frac{(3+2x)}{2x(3+4x) - (1+2x)(b-1)^2} &> \frac{1}{4x - (b-1)^2} \\
(3+2x)(4x - (b-1)^2) &> 2x(3+4x) - (1+2x)(b-1)^2 \\
3x &> (b-1)^2,
\end{aligned} \tag{21}$$

is true under Assumption 1.

Comparing the amount of public goods as $g_2 > g_1$ reduces to

$$\begin{aligned}
-\frac{(3+2x)(b-1)x}{2x(3+4x) - (1+2x)(b-1)^2} &> \frac{x(b-1)}{-4x + (b-1)^2} \\
\frac{(3+2x)}{2x(3+4x) - (1+2x)(b-1)^2} &> \frac{1}{4x - (b-1)^2},
\end{aligned}$$

which must be true since (21) holds. Comparing the size of the shadow economy $F(\bar{c}_1) > F(\bar{c}_2)$

$$\begin{aligned}
\frac{1}{2} \left(\frac{-2x + (b-1)^2 + (-4x + (b-1)^2)}{-4x + (b-1)^2} \right) &> \frac{(1+2x)(3x - (b-1)^2)}{2x(3+4x) - (1+2x)(b-1)^2} \\
\left(\frac{1}{4x - (b-1)^2} \right) &> \frac{(1+2x)}{2x(3+4x) - (1+2x)(b-1)^2} \\
2x(3+4x) &> 2x(2+4x)
\end{aligned}$$

is true.

For the profits of the legal firm $\pi_{l1} < \pi_{l2}$

$$\begin{aligned}
1 - z^2 + \frac{(b-1) + 2x}{-4x + (b-1)^2} x &< (1 - z^2) - \frac{(2x + (b-1))(3+2x)x}{2x(3+4x) - (1+2x)(b-1)^2} \\
\frac{1}{4x - (b-1)^2} &< \frac{(3+2x)}{2x(3+4x) - (1+2x)(b-1)^2},
\end{aligned}$$

is true since (21) is true.

For the illegal firm we show that $\pi_{11} > \pi_{12}$, which reduces to showing that $bg_1 > b g_2 - r_2$

$$\begin{aligned} \frac{x(b-1)b}{-4x+(b-1)^2} &> -\frac{b(3+2x)(b-1)x-2x((b-1)^2-3x)}{2x(3+4x)-(1+2x)(b-1)^2} \\ -(b-1) &< 4x \end{aligned}$$

which is true under Assumption 1.

The payoffs for the government and the mafia are

$$\begin{aligned} G_2 &= \frac{1}{2}z^2 + \frac{(3+2x)^2(4x-(b-1)^2)}{2(2x(3+4x)-(1+2x)(b-1)^2)^2}x^2, \\ M_2 &= \frac{2x(x+1)(3x-(b-1)^2)^2}{(2x(3+4x)-(1+2x)(b-1)^2)^2}. \end{aligned}$$

Comparing the government benefits $G_2 > G_1$,

$$\begin{aligned} \frac{1}{2}z^2 + \frac{(3+2x)^2(4x-(b-1)^2)}{2(2x(3+4x)-(1+2x)(b-1)^2)^2}x^2 &> \frac{1}{2}z^2 + \frac{x^2}{2(4x-(b-1)^2)^2} \\ \frac{(3+2x)^2}{(2x(3+4x)-(1+2x)(b-1)^2)^2} &> \frac{1}{(4x-(b-1)^2)^2}, \end{aligned}$$

is true under Assumption 1.

B.2 Cournot vs. Stackelberg

Comparing the optimal solutions in a Cournot game to those of a Stackelberg game, and proposing $t_3 > t_2$ suggests $t_3 - t_2 > 0$.

$$\begin{aligned} \frac{4x^2(1+x)(3+2x)}{(1+2x)(8x(1+x)-(1+2x)(b-1)^2)} + z^2 - \frac{2x^2(3+2x)}{2x(3+4x)-(1+2x)(b-1)^2} - z^2 &> 0 \\ \frac{2x^2(3+2x)}{(1+2x)} \frac{4x(1+x)-(b-1)^2}{(2x(3+4x)-(1+2x)(b-1)^2)(8x(1+x)-(1+2x)(b-1)^2)} &> 0 \end{aligned}$$

is true since $4x(1+x) > (b-1)^2$ as $4x > (b-1)^2$ under Assumption 1.

Comparing the amount of public goods $g_2 > g_3$ shows that

$$\begin{aligned} -\frac{(3+2x)(b-1)x}{2x(3+4x)-(1+2x)(b-1)^2} &> -\frac{(3+2x)(b-1)x}{8x(1+x)-(1+2x)(b-1)^2} \\ \frac{1}{2x(3+4x)-(1+2x)(b-1)^2} &> \frac{1}{8x(1+x)-(1+2x)(b-1)^2} \end{aligned}$$

since $8x(1+x) - (1+2x)(b-1)^2 > 2x(3+4x) - (1+2x)(b-1)^2$.

Comparing the rents suggests that $r_2 > r_3$

$$\begin{aligned} -\frac{2x\left((b-1)^2 - 3x\right)}{2x(3+4x) - (1+2x)(b-1)^2} &> -\frac{2x}{(1+2x)} \frac{(1+2x)(b-1)^2 - x(6x+5)}{8x(1+x) - (1+2x)(b-1)^2} \\ \frac{3(1+2x)}{2x(3+4x) - (1+2x)(b-1)^2} &> \frac{6x+5}{8x(1+x) - (1+2x)(b-1)^2} \end{aligned}$$

is not true, thereby $r_3 > r_2$. This is also enough to prove that $F(\bar{c}_3) > F(\bar{c}_2)$ as

$$\frac{x(6x+5) - (1+2x)(b-1)^2}{8x(1+x) - (1+2x)(b-1)^2} > \frac{(1+2x)\left(3x - (b-1)^2\right)}{2x(3+4x) - (1+2x)(b-1)^2}. \quad (22)$$

The payoffs for the government and the mafia are

$$\begin{aligned} G_3 &= \frac{1}{2}z^2 + \frac{(2x+3)^2 x^2}{2(1+2x)\left(8x(1+x) - (1+2x)(b-1)^2\right)}, \\ M_3 &= \frac{2x(1+x)\left((1+2x)(b-1)^2 - x(6x+5)\right)^2}{(1+2x)^2\left(8x(1+x) - (1+2x)(b-1)^2\right)^2}. \end{aligned}$$

To show that $G_3 > G_2$

$$\begin{aligned} \frac{1}{2}z^2 + \frac{(2x+3)^2 x^2}{2(1+2x)\left(8x(1+x) - (1+2x)(b-1)^2\right)} &> \frac{1}{2}z^2 + \frac{(3+2x)^2 x^2 \left(4x - (b-1)^2\right)}{2\left(2x(3+4x) - (1+2x)(b-1)^2\right)^2} \\ \frac{1}{(1+2x)\left(8x(1+x) - (1+2x)(b-1)^2\right)} &> \frac{4x - (b-1)^2}{\left(2x(3+4x) - (1+2x)(b-1)^2\right)^2} \end{aligned}$$

reduces to $\left(2x(3+4x) - (1+2x)(b-1)^2\right)^2 > (1+2x)\left(4x - (b-1)^2\right)\left(8x(1+x) - (1+2x)(b-1)^2\right)$.

After simplifying yields $(3+4x)^2 > 8(1+2x)(1+x)$ which is true for all x .

To show that $M_3 > M_2$

$$\begin{aligned} \frac{2x(1+x)\left((1+2x)(b-1)^2 - x(6x+5)\right)^2}{(1+2x)^2\left(8x(1+x) - (1+2x)(b-1)^2\right)^2} &> \frac{2x(x+1)\left(3x - (b-1)^2\right)^2}{\left(2x(3+4x) - (1+2x)(b-1)^2\right)^2} \\ \frac{\left((1+2x)(b-1)^2 - x(6x+5)\right)^2}{\left(8x(1+x) - (1+2x)(b-1)^2\right)^2} &> \frac{(1+2x)^2\left(3x - (b-1)^2\right)^2}{\left(2x(3+4x) - (1+2x)(b-1)^2\right)^2} \end{aligned}$$

is true since (22) is true.

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