How does corruption drive illegal deforestation in Amazon Forest?

Abstract: The resent policy imposes heavier penalties and closer surveillance to individuals engaged in illegal deforestation. This paper disputes the alleged effects of this policy. A new variable is added to the problem, the corrupt behavior. An analysis is made of how information asymmetry between the government and the official in charge of inspection may affect deforestation. By using Agency Theory, a simultaneous static game of complete/perfect information between the landowner and the official is simulated. Then, the resulting Nash equilibrium is analyzed. Results show that the actual relationship between the government and the Brazilian Institute for Environment and Natural Resources officials (IBAMA) promote incentive do collusion. Also, the results shown that a policy oriented, only, to surveillance of landowners is a necessary but not sufficient condition to guarantee the conservation of the Amazon rainforest. Also, harsher policies may lead up, in some cases, to increased illegal deforestation.

Keywords: Collusion, Nash equilibrium, deforestation.

JEL Classification: Q10, Q18, Q23.

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1 Introduction

Deforestation is a major environmental problem in countries with great extensions of rainforest, like Thailand, Malaysia, Indonesia, Congo, Ghana and Brazil, among other tropical countries. There is substantial research on various aspects of deforestation, and economic reasons stand out as primary causes of the problem. Third world countries are the most at risk of deforestation due to weak or non-existent institutions (CONTRERAS-HERMOSILLA, 2001).

Given the pressing importance of the matter, many countries, among them African ones, are trying to increase public awareness of the problem, chiefly in rural areas, (NAIR E KOMERO, 2004). In Brazil, deforestation of the Amazon rainforest is currently a much debated and talked about issue in the national media.

According to a 2007 study by Instituto Nacional de Pesquisa Espacial (INPE), the rate of deforestation decreased in the 1988-2007 period. The main culprits of deforestation are cattle ranchers (60 – 70%), followed by squatters (30 – 40%). Timber extraction and civil engineering projects are responsible for fewer than 5% of total deforestation.

The economic aspect of the matter inspired endogenous policies that take in account the profit seeking behavior of the agents, as a way to minimize deforestation. One such policy is soil management, which has been considered an effective way of minimizing deforestation.

When endogenous policies don't show results, the government imposes exogenous policies such: (1) delimitation of the legally deforested areas; (2) applying fines and; (3) surveillance activities. The current policy is focused on increasing surveillance and heavier penalties to the landowners. IBAMA has been one important instrument of government for implementing the such policies.

According to data (2008), Mato Grosso State has the biggest deforested area. Some 1,120 square kilometers of the Amazon rainforest have been deforested. Of this area, about 794 square kilometers are in Mato Grosso State, or 70% of the total (GREENPEACE, 2008).

The current federal administration plans to decrease deforestation by introducing more severe penalties and stricter surveillance. However, this policy doesn't contemplate the possibility of corruption by the officials. According to VIANA (1998) and AMACHER (2006b), 80% of the timber extracted from the Amazon forest is illegal. This fact indicates that, beyond increased surveillance, corrupt practices must be dealt with, because corruption is possibly one important cause for such high percentual of illegal deforestation.

There is substantial literature on the economic causes of corruption. The subject is no longer ignored in the environment economics field, and some research points to corruption as an important determinant in the increase of deforestation. Amacher (2006 a, 2006 b) assesses the importance of taking corruption into account in fighting illegal deforestation.[1]

Some international studies on deforestation (PELLIGRINI, 2007; WIBOWO and BYRON 1999; PALO 2002; AMACHER 2006, among others), warn about corrupt practices in forest management and suggest harsher policies (heavier fines, more severe punishment for those who organize corruption schemes (i.e., landowners), as a way of curtailing illegal deforestation. However, the information asymmetry that results of weak institutions stimulates opportunists behavior, (NAIR and KOWERO, 2004).[2] The existence of collusion undermines the effectiveness of the government policies. That is, in the presence of information asymmetry, corrupt practices cannot be weeded out just by imposing harsher punishment for corruption.

Research in Brazil on deforestation is concerned mainly with dealing with squatters and ranchers and with improving soil management techniques.[3] Information asymmetry

[1] Various works like: Contreras-Hermosilha (2001), (2003), Pelligrini (2007), Wibowo and Byron (1999), Palo (2002), McAllister (2005), Kowero and Nair (2004), analyze the role of corruption in stimulating deforestation..

[2] Existence of information asymmetry and the resulting corrupt practices persuaded some researchers that heavier penalties and closer surveillance are the most effective policies. In this paper game theory is used to show that heavier penalties not necessarily decrease the rate of deforestation. On the contrary, it is shown that, due to information asymmetry, these harsher policies could lead to increased deforestation.

[3] These matters are relevant in fighting illegal deforestation. Nevertheless this paper intends to show that corruption is an issue that cannot be neglected..

almost always breeds corruption and conduces to results different from the ones intended. So, one policy of closer surveillance and harsher punishment to squatters and ranchers may not result in less deforestation, because surveillance and dispensing fines are not directly controlled by the central government (i.e., the high rank officials), but by low rank, low salaries officials. So, assuming the existence of information asymmetry between government and low rank officials appears an agency problem. In such a situation, fraud is a possible equilibrium outcome, leading to illegal deforestation.

This paper puts in question the partial results of the policy of increased surveillance and heavier penalties for squatters, ranchers, lumber producers and others activities that implies in illegal deforestation. The central point of this paper, (a point neglected in other papers), is the possibility of collusion between the landowner and the IBAMA official. This collusion, besides eliminating the effects of penalties on the landowners also guarantees that, under certain conditions, the penalties for corrupt officials (i.e., the ones with inspection duties) may not result in less illegal deforestation. This possibility is contrary to the mainstream international research on corruption. Imposing penalties is a necessary but not sufficient condition to eliminate collusion. The central result of this paper is that, when there is information asymmetry, heavier penalties for the landowner may result in more illegal deforestation.

To analyze how the relationship between the landowner and the IBAMA official affect the deforestation level, it is used the game theory modeling. The model is constructed in an easy way, by supposing the existence of a single relationship between the players under a complete/perfect information environment. The model used here, due the static structure, has several limitations: (1) it ignores the importance of credibility in the bargaining game (e.g., a present issue in dynamic games); (2) it could consider a game of incomplete information between the Government and the IBAMA official. Despite these weaknesses, the model constructed here is a first attempted to show the possible failures of the present policies adopted by the Government.[4]

Besides this introduction this paper presents the model in section 2 and final remarks in section 3.

2 The model

In the model, there are three players: the landowner, the government official and the government. A proportion Υ of the number of officials is composed of corrupt individuals.[5] In order to formalize the model, is analyzed the behavior of a representative landowner, a representative corrupt official and the government. The main objective is to obtain insight on how information asymmetry affects deforestation.

Let $\overline{T}$ be the size of the forest which belongs to the representative landowner, where t^i the lower bound is and t^s the upper bound. Thus, $\overline{T}$ Is a compact set. The landowner is allowed to clear the forest up to the limit t_m , which is a number between the lower and upper bounds, (i.e., $t_m = \frac{1}{2}t^i + \frac{1}{2}t^s$). If the landowner surpasses the upper limit, he receives a fine (δ). Surveillance is not done directly by the government, but by a hired official. After the area is inspected, the hired official reports to the government possible occurrence of illegal deforestation. At the end of the period, the official earns a salary (w), not contingent on his reports.[6]

The landowner can choose whether to clear the forest up to the allowed limit or to go beyond the limit and risks to be fined. That is, there are two states of nature: when the landowner clears more forest than he is allowed to $(t^i > t_m)$ and when the landowner respects the limit $(t^i \leq t_m)$.[7] The real state of nature is not known by the government. That is so because the official may decide to not report illegal deforestation.[8] If all officials are honest $(\Upsilon = 0)$, then the reports received by the government precisely inform whether the landowner cleared more forest than he was allowed to. If the honesty of officials is

[4] The relationship between the landowner, the IBAMA official, and the government could be modeled using a dynamic game of incomplete information. Focusing on the relationship between the government and the IBAMA official, it could be created an "investigation game" where the IBAMA official can be investigated by an internal/external auditor hired directly by the government. If it is supposed the inexistence of the agency problem between Government and the auditor, the "investigation game" would be solved by the analyses of the resulting equilibrium. In this kind of game (i.e., dynamic games with incomplete information) it can be found many equilibriums, namely Separating, Pooling, and Hibrid equilibrium (for a survey about these matters see FUDENBERG and TIROLE, 1991). In such framework, it would be possible to analyze, in a more technical approach, how the Government's policies can influence the collusion strategies from the players.

[5] Only the official belonging to this group has their behavior modeled.

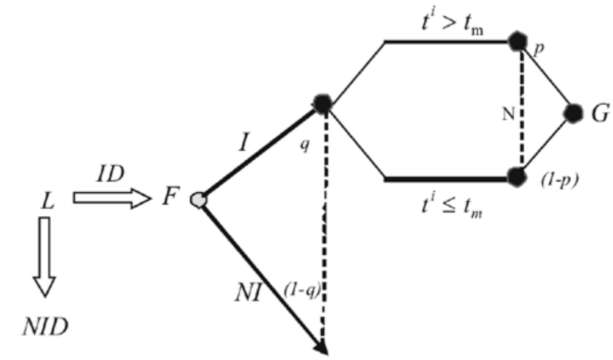
[6] The salary of the official is not contingent on government revenue from fines on landowners that cleared Forest beyond the upper limit.

[7] Under a policy of giving fines which magnitude is not correlated to the magnitude of the damage done (illegal deforestation), the following result is trivial: $\forall \delta \in \Re^+ : \forall t^i$ such that : $t^i > t_m \Rightarrow t^j = t_s, \forall j > i;\ i, j \in ¥$,where the index represents the degree of deforestation (the greater the index, the bigger the amount of deforestation). Since the penalty is fixed and known, the dominant strategy for the landowner is to clear all his land. That is, this policy brings about the possibility of total deforestation.

[8] We assume that the official has the means to appraise the real state of nature when inspecting a landowner's lot.

questionable, the government has just a probability distribution over the real state of nature. One aim of this paper is to find out whether the proposed relationship involving the players incentive the collusion. This relationship is depicted in Figure 1.

Figure 1: The Actual Sequence of relationships among landowner, official and government



Source: Author's elaboration

Where the landowner, ***L*** , can choose to illegally clear the forest, ***ID***, or not ***NID***. The landowner may be inspected, ***I***, (or not ***NI***) ,by the official, ***F***, with probability ***q***. If an investigation takes place, the official finds out whether illegal deforestation occurred, $t^i > t_m$, or not, $t^i \leq t_m$. The government, ***G*** , receives the report, but doesn't know, for sure, the actual state of nature. It just has a probability distribution of the real state of nature. The probability that the state of nature is that illegal deforestation took place is ***p***.

Given the relationship involving the three players, it is possible to ascertain the effects of collusion between the landowner and the corrupt official.[9] The analysis is made by means of simultaneous, complete/perfect information, games between the landowner and the IBAMA official.

Equilibrium in a simultaneous game: landowner versus official

In the game between landowner and official, let the compact set $s_i = \{s_1, s_2\}$, be the actions space for each player. There is a pay-off function for each player, suitable for the strategy adopted in response to the one adopted by the other player. For clearer explanation, the game played is a simultaneous one, with perfect/complete information. The action's set for each player, are:

$$s_i = \begin{cases} s_1 = collude \\ s_2 = not\ collude \end{cases}$$

The landowner's profit, $\pi(p, v)$ is a function of the prices level ***p*** and of output ***v***,[10] Sales depend dire ctly on the deforested area ***t***, where $t \in \{t_i, t_m\}$ and $v = \lambda(t)$. It is assumed that: $\lambda_t > 0 \wedge \lambda_{tt} = 0$. In the special case that the coefficient equals the unity, the landowner's profit is $\pi(p, t)$. The official's pay-off is given by the salary ***w*** earned in the end of the game.

To make feasible the game, is necessary to analyze the case of illegal deforestation, that is, when $t^i > t_m$.[11] When illegal deforestation takes place, the landowner can allure the official by proposing collusion. The official may agree to collude or not.[12] If the official accepts, he has a pay-off given by $w + \Delta w(t > t_m)$, where $\Delta w(t > t_m)$ represents the bribe paid by the landowner. The landowner's pay-off, in this case, is given

9 This paper considers "ex-post" collusion. That is, which occurs after the illicit action is known. But there is also "ex-ante" collusion, in which collusion is considered bearing in mind the probability of being caught practicing the illicit action. For example in, "ex-post" collusion see: Mookherjee and Png (1995).

10 For example, the landowner who engages in logging has a profit that is a function of the price of the cubic meter and the quantity of timber extracted from the forest. For the sake of simplicity, production costs (capital and labor) are considered as zero.

11 When there was not illegal deforestation, landowner and official have no reason to collude. So the situation of interest is the players´ behavior in the event of illegal deforestation.

12 Any one of the players can propose collusion. That is, once the official finds out about the illicit act, he may offer a collusion agreement to the landowner.

by $\pi(p,t)+\Delta\pi(p,t>t_m)-\varepsilon$, where $\Delta\pi(p,t>t_m)$ represents the earnings from clearing the forest beyond the allowed area, and ***g*** represents the fine due to the official, $\Delta\pi(p,t>t_m)\in\Re^{+}$ and. $\varepsilon\in\Re^{+}$[13] In the event of illegal deforestation and the official is not willing to take the bribe, his pay-off is the salary and the landowner's pay-off is $\pi(p,t)+\Delta\pi(p,t>t_m)-\delta$, where δ is the fine imposed, to the landowner, by the government, $0<\varepsilon\le\Delta\pi(p,t>t_m)<\delta$, $\delta\in\Re^{+}\le\infty$.[14]

The game in its normal form is:[15]

Official		Landowner: Collude	Landowner: Not collude
	Collude	(D, A)	C, B
	Not collude	C, B	C', B'

Where: $A=\pi(p,t)+\Delta\pi(p,t>t_m)-\varepsilon$

$B=\pi(\overline{p},t)+\Delta\pi(\overline{p},t>t_m)-\delta$

$C=w$

$D=w+\Delta w(t>t_m)$

$B'=\pi(\overline{p},t)+\Delta\pi(\overline{p},t>t_m)-\delta-\kappa$

$C'=w-i$

The analysis of the strategies shows that there is a dominant strategy to both players. That is, the equilibrium is reached through dominant strategies.

Typology of the Equilibrium [16]

The uniqueness, of the Nash equilibrium, for the present game, deserves a better attention. For the resolution of the game, it is verified that: assuming first that the officer plays in making collusion (c), the landowner will, also, wants to e collude (c), because $A>B$. If the officer chooses the option not collude (nc), the landowner is indifferent in playing "c" or "nc". Thus, the only way to get a dominant strategy, from the landowner point of view, is to assume that: $\forall\kappa\in\Re^{+}$, the pay-off for the landowner is given by: $B'=\pi(\overline{p},t)+\Delta\pi(\overline{p},t>t_m)-\delta-\kappa$, when the official play "nc" and he/she plays "nc". Thus, is this situation, there is a dominant strategy for the landowner, because $B>B'$. Regarding to the officer strategies, it found that: when the landowner plays "c" it has as strategy to play "c", because $D>C$. When the landowner play "nc" he/she is indifferent in playing "c" or "nc". Following the same method before, to get an dominant strategy, from the official point of view, it is assumed that: $\forall i\in\Re^{+}$, if he/she plays "nc", the pay-off is $C'=w-i$, when the landowner plays "nc". The use of these assumptions, without losses, simplifies the analysis, assuring the impossibility of multiple Nash equilibrium.

Equilibrium and "ex-post" collusion: effects on illegal deforestation

The Nash equilibrium is reached through strategies (D, A). So, the existing incentives stimulate ex-post collusion. The following lemma presents this result.

Lemma 1: *In a situation where there is no information symmetry between government and inspecting official, the resultant equilibrium in the simultaneous game between the fiscal and the landowner reaches a single stable equilibrium through strategies (D,A).*

Proof:

The proof comes from the classic way of solving static, simultaneous, perfect information games in order

[13] Collusion makes possible to landowner and official to split the fine due to the government. Bargaining power is considered the same to both parties. It will be seen how shifts in the bargaining power of the parties do not affect illegal deforestation. The possibility of collusion is profitable to the landowner if $\Delta\pi(.)-\varepsilon>\Delta\pi(.)-\delta$.

[14] In the event of illegal deforestation, the fine is split between landowner and official. The landowner's amount enters in $\Delta\pi(.)$. The fine for illegal deforestation is defined as $\delta=\varepsilon+x$ where x represents the part not deductible from the landowner's profit. Thus, for the same bargaining power, $x=\Delta w(\overline{p},t>t_m)$. The condition that the fine be limited, postulated by other researchers, is not necessary. In fact, this paper shows that, in the presence of information asymmetry, even heavy fines $(\delta\to\infty)$ cannot promote a first best solution. On the contrary, such policies may bring worse outcomes for society.

[15] The components of the pay-offs represented in the game are: the right side represent the official pay-off and the left side represent the landowner pay-off.

[16] The uniqueness condition for the equilibrium, (D, A) is just to make easier the analysis. It is easy to show that the game has a weak equilibrium in dominant strategies. Thus, the uniqueness is just to guarantee a strong equilibrium in

to obtain Nash equilibrium (see FUDENBERG e TIROLE, 1991).

The previous analysis gives an insight into the effects of corruption on illegal deforestation. Given the assumption of rationality of landowner and the official, the present regulatory and surveillance apparatus, landowner-oriented, doesn't pay sufficient attention to the reality of corruption and to the extent that it facilitates illegal deforestation.

So, auditing the officials' reports and imposing penalties to mitigate corrupt acts are necessary measures in checking collusion.

To see how punishing corrupt officials affects the practice of collusion, the same simultaneous game is played, but this time the official considers the probability of being caught and punished. [17]

Considering the game in the previous figure, now we have:

$$A = (1-\omega)\left(\pi(\bar{p},t) + \Delta\pi(\bar{p},t>t_m) - \varepsilon\right) + \omega\left(\pi(\bar{p},t) + \Delta\pi(\bar{p},t>t_m) - (\varepsilon+\alpha)\right)$$
$$B = \pi(\bar{p},t) + \Delta\pi(\bar{p},t>t_m) - \delta$$
$$C = w$$
$$D = (1-\omega)(w + \Delta w(t>t_m)) + \omega(w + \Delta w(t>t_m) - \eta)$$

Where ω is the probability that the official suffers investigation; α is the punishment dispensed to the landowner for corrupting the official and η is the punishment dispensed, to the official, for engaging in collusion.

The dominant equilibrium strategy, (D, A) to the official demands satisfying the following: [18]

$$(1-\omega)(w + \Delta w(t>t_m)) + \omega(w + \Delta w(t>t_m) - \eta) > w \tag{1}$$

To the landowner the condition is:

$$(1-\omega)\left(\pi(\bar{p},t) + \Delta\pi(\bar{p},t>t_m) - \varepsilon\right) + \omega\left(\pi(\bar{p},t) + \Delta\pi(\bar{p},t>t_m) - (\varepsilon+\alpha)\right) > \pi(\bar{p},t) + \Delta\pi(\bar{p},t>t_m) - \delta \tag{2}$$

So, from the moment that the policy of auditing the reports is implemented, there is a set of values that satisfy the above stated conditions.

Lemma 2: *In a simultaneous, complete information game, the policy of auditing reports mitigate collusion, if the following conditions are satisfied:* $\omega > \frac{\Delta w(\bar{p},t>t_m)}{\eta}$ *for the official and* $\omega > \frac{\delta-\varepsilon}{\alpha}$ *for the landowner.*

Proof:

Nash equilibrium in dominant strategies demands that: no matter whether the official decides to collude or not, the best strategy for the landowner is to seek a collusion and vice-versa. Considering the uniqueness conditions, this implies conditions (1) and (2). Solving those equations, gives:

$$\omega < \frac{\Delta w(\bar{p},t>t_m)}{\eta} \qquad \omega < \frac{\delta-\varepsilon}{\alpha}$$

Jointly, these two conditions can be integrated in just one. Suppose that: $\eta = \alpha$ *, thus the Nash "Collusion"equilibrium condition, is:*

$$\omega < \frac{\Delta w(\bar{p},t>t_m)}{\eta}$$

[17] It is assumed that when the government investigates an official, it ascertains the true state of nature, meaning that it finds out whether his report is true. .

[18] Only the conditions for a single equilibrium in pure strategies are treated here in (D, A). Conditions (1) and (2), complement each other when a player decides to collude. The dominant strategy for the official is colluding when the landowner decides to collude, and vice-versa. So, condition (1) demands fulfilling condition (2) and vice-versa.

Since, $\Delta w(.) = x$ *holds, for the same bargaining power.* [19]

Those are the "Nash" collusion conditions. So, the complementary conditions are stated in lemma 2.

The conditions above are the trade-off resulting of the adoption by the government of a policy of checking collusion.

When the landowner is not directly punished for colluding, $\alpha = 0$, the strategy of colluding is always dominant, provided that $\delta > \varepsilon$, which, in its turn, is always satisfied.

The collusion is a dominant strategy to the official whenever: $\eta = 0$. So its crucial that the auditing policy be complemented by penalties. However, imposing penalties is a necessary but not sufficient condition, as the official weighs the penalty against the gain in bribes paid. [20]

Theorem 1: *Under asymmetric information environment, the policy of investigating and penalizing officials is a necessary but not sufficient condition to hinder corrupt officials.*

Proof:

Suppose, for the same bargaining power, that: $\eta = \alpha$. *If* $\eta = 0$ *If , then the collusion condition implies that:* $\Delta w(\bar{p}, t > t_m) > 0$, *which is satisfied by definition. If* $\eta \neq 0$ *and* $\omega \in (0,1]$, *the collusion condition implies that:* $\omega \eta < \Delta w(\bar{p}, t > t_m)$, *so that heavier penalties to the officials,(i. e.,* $\Delta\eta > 0$*), violate the condition if* $\Delta w(p, t > t_m)$ *stays constant, (i.e.,* $\Delta w(.) < (\eta + \Delta\eta) \cdot \omega$ *). However, the condition is not violated (i.e.,* $\Delta w^*(.) > \omega \cdot \eta^*$, *where* $\Delta w^*(.) > \Delta w(.)$, *and* $\eta^* > \eta$ *), if and only if, for a given* ω *, there is* $\Delta\eta$ *, such that:* $\Delta\eta < \Delta(\Delta w(\bar{p}, t > t_m))$. *In this case heavier penalties cannot mitigate the corruption problem, (i.e., the Nash condition is always satisfied).*

From the stated theorem it is possible to conclude that a policy of auditing hinder corruption but doesn't guarantee its eradication, due to the conditions stated previously. This results is contrary the most research in this field.

Another outcome of Theorem 1 is that increasing the penalty for illegal deforestation, , may backfire the government targets, stimulating collusion and expanding illegal deforestation.

Previously $\delta = \varepsilon + x$ was defined, where x is the part of the fine kept by the landowner. So, if the conditions stated in Theorem 1 hold, increasing the fines for illegal deforestation just raises the amount split between the colluding landowner and official.[21] The following theorem sums up the conclusion, which is distinct from other researchers' on the matter.

Theorem 2: *For any* $\omega \in (0,1]$ *, an increase of the penalty for landowners engaging in illegal deforestation,* δ *, engenders greater incentives for collusion, increasing illegal deforestation.*

Proof:

Assume that both individuals are in a condition of indifference, and that those conditions stated in theorem 1 holds. That is, suppose that the following conditions hold:

$$(1-\omega)(w + \Delta w(t > t_m)) + \omega(w + \Delta w(t > t_m) - \eta) = w \tag{3}$$

$$\begin{aligned}&(1-\omega)(\pi(p,t) + \Delta\pi(p, t > t_m) - \varepsilon) + \\ &+ \omega(\pi(p,t) + \Delta\pi(p, t > t_m) - (\varepsilon + \eta)) = \pi(p,t) + \Delta\pi(p, t > t_m) - \delta\end{aligned} \tag{4}$$

[19] The general case satisfied the following sub-cases:

$$\begin{cases} \alpha > \eta \Rightarrow \dfrac{\Delta w(.)}{\eta} > \dfrac{\Delta w(.)}{\alpha} & (a) \\ \alpha = \eta \Rightarrow \dfrac{\Delta w(.)}{\eta} = \dfrac{\Delta w(.)}{\alpha} & (b) \\ \alpha < \eta \Rightarrow \dfrac{\Delta w(.)}{\eta} < \dfrac{\Delta w(.)}{\alpha} & (c) \end{cases}$$

to each one sub-case, there is a special condition for the Nash equilibrium. Case (a): the existence of Nash Equilibrium implies that: $\omega < \frac{\Delta w(.)}{\alpha}$ case (c): $\omega < \frac{\Delta w(.)}{\eta}$.

[20] The penalty is a sufficient condition when $\omega = 1$ That is, when $\eta > \Delta w(\bar{p}, t > t_m)$. This point is seen in the paper and is crucial to understand why a policy of heavy penalties, δ , may increase instead of abate illegal deforestation.

[21] Is this case, the increasing in the penalty just change the bargaining power between then landowner and the official. Is easy to show that, this situation implies that: $x \to 0$ when $\delta \to \infty$:

Assume that $\omega \in \Re^{+}$, $\omega < 1$, *so, for* $\Delta\delta > 0$,, *condition (3) is satisfied by the inequality:*

$$(1-\omega)(w+\Delta w(t>t_m)^*)+\omega(w+\Delta w(t>t_m)-\eta)>w$$

Where: $\Delta w(t>t_m)^* > \Delta w(t>t_m)$

And:

$$\frac{\partial[E(G)_O]}{\partial\delta}=\frac{\partial[E(G)_O]}{\partial\varepsilon}\cdot\frac{\partial\varepsilon}{\partial\delta}>0,\ since: \Delta w(t>t_m)=\varepsilon$$ [22]

Where $E(G)_O$ *represent official expect gain. So, the official agrees to a collusion proposed by the landowner. It remains to be seen how the landowner evaluates a collusion proposed by the official in the event of increased penalization for illegal deforestation. Condition (4) is the situation in which the landowner is indifferent with respect to collude or not. For* $\Delta\delta > 0$, *we have:*

$$(1-\omega)(\pi(p,t)+\Delta\pi(p,t>t_m)^*-\varepsilon^*)+$$
$$+\omega(\pi(p,t)+\Delta\pi(p,t>t_m)^*-(\varepsilon^*+\alpha))>\pi(p,t)+\Delta\pi(p,t>t_m)-\delta^*$$

Where $\Delta\pi(p,t>t_m)^* > \Delta\pi(p,t>t_m)$

And

$$\frac{\partial[E(G)_L]}{\partial\delta}>0$$

The identity $\varepsilon = \delta - x$ *was used.*

Where $E(G)_L$ *represent the landowner expect gain.* [23]

Thus, there is a incentive for collusion, form the landowner point of view.

The previous theorem allows seeing that, in the presence of information asymmetry, the adopted policies may backfire. The research on the effects of corruption on illegal deforestation has so far neglected the adverse results due to the failure of the policies in mitigating collusion.

Theorem 2 considers the probability that the official is investigated, ω , as given ($\omega = \bar{\omega}$). The indifference condition to both players is:

$$\bar{\omega}=\frac{\Delta w(p,t>t_m)}{\eta} \quad (5)$$

$$\bar{\omega}=\frac{\Delta w(p,t>t_m)}{\alpha}, \quad (6)$$

Where $x = \Delta w(.)$, (i.e., the same bargaining power).

An increase in the fine for illegal deforestation increases the numerator for both conditions. The sole way to offset the increase in the numerator, in the case of the official, is increasing ω , or η In the case of the landowner, it is necessary to increase ω or α.

Corollary 1: The p*olicy of heavier penalties mitigates collusion, if and only if the conditions (5) and (6) are violated. Thus, It is necessary to harden the punishment of the corrupt official or, alternatively, to increase surveillance on the officials.*

Proof:

1st case: Same bargaining power: $\Delta w(t_i > t_m, p) = \frac{1}{2}\delta^* = x$.

Since: $\delta^* = \delta + \tau$ *, where* $\tau \in \Re^{+}$ *it follows that:*

$\forall\delta^* \in \Re^{+}$, ***implies that***: $\Delta(\Delta w(.)) \in \Re^{+}$ ***and*** $\Delta x \in \Re^{+}$ *, as a result:*

[22] When the penalty increase, (i.e., $\Delta\delta \in \Re^{+}$). there are, several, sub-cases, depending of the bargaining Power:

$$\Delta\delta > 0 \Rightarrow \begin{cases} x\uparrow \ and\ \varepsilon\uparrow & (I) \\ x = \bar{x}\ and\ \varepsilon\uparrow & (II) \\ x\uparrow \ and\ \varepsilon = \bar{\varepsilon} & (III) \end{cases}$$

The case (I) represent the same bargaining power, (i.e., $\Delta\varepsilon = \Delta x$).

[23] Where:
$E(G)_L = (1-\omega)(\pi(p,t)+\Delta\pi(p,t>t_m)-\varepsilon)$
$+\omega(\pi(p,t)+\Delta\pi(p,t>t_m)-(\varepsilon+\alpha))$
and
$E(G)_O = (1-\omega)(w+\Delta w(t>t_m))+\omega$
$(w+\Delta w(t>t_m)-\eta)$.

$\Delta\left(\Delta w(.)\right) > \Delta\eta \rightarrow \bar{\omega} < \dfrac{\Delta w^*(.)}{\eta^*}$ *so, the indifference condition in the case of the official is violated and he agrees to collude. But, if:* $\Delta\left(\Delta w(.)\right) < \Delta\eta \rightarrow \bar{\omega} > \dfrac{\Delta w^*(.)}{\eta^*}$ *, the official doesn't collude.*

$\Delta x > \Delta\alpha \rightarrow \bar{\omega} < \dfrac{\Delta x^*}{\alpha^*}$*, that is, the indifference condition of the landowner is violated, and he seeks to collude. The opposite is:* $\Delta x < \Delta\alpha \rightarrow \bar{\omega} > \dfrac{\Delta x^*}{\alpha^*}$*, that leads to the decision of avoiding collusion.*

2nd case: Unequal bargaining power: $\Delta w(t_i > t_m, p) \neq \dfrac{1}{2}\delta^*$*, (i.e., case (II) or (III). see note 21)*

The demonstration is the same, but taking into account that $\forall \delta^* \in \Re^+$*, there is a region* R_d*, where* $R_d : \{x_i : \Delta x \in \Re_0^+\}$*. The region, R, represent the real line set for which the collusion condition holds for any given x, provided that the landowner's profit from colluding is positive, or:* $\varepsilon < \delta$ *. Thus the case (III), (see note (21)), never take a place, because the bargaining power of the landowner goes to zero, as the penalty goes to infinity, (i.e.,* $x \rightarrow 0$ *as* $\delta \rightarrow \infty$ *). Thus, as penalty increase, the region* R_d *is, formally, represented by:* $R_d : \{x_i : \Delta x \in \Re\}$*, (i.e., the real line,* $\Re$*).*

From the stated above the following corollary is derived:

Corollary 2: *Bargaining power doesn't influence the landowner's decision, provided that the above condition holds. Any* $\varepsilon \leq \delta$ *, weighted by the probability of being investigated leads to collusion.*

The result above shows that the existing policy may increase illegal deforestation, even when it is associated with the practice of auditing reports. Besides internal audits there must be other legal measures that assure the punishment of individuals engaging in corrupt practices.

The following chart sums up the effects of each government policy:

Chart 1: Summary of the effects of the government policies

Policy	*Effect*			
	Situation: $\Delta\eta$, Δx, $\Delta\alpha$ $\Delta(\Delta w(t > t_m))$	*Landowner's strategy*	*Official's strategy*	*Illegal deforestation*
Increase "δ*", and* $\omega = 0$.	$\Delta(\Delta w(t > t_m)) \in \Re^+$	*To collude*	*To collude*	*Increases*
	$\Delta\alpha = 0$, $\Delta\eta = 0$			
Increase "δ*", and* $\omega = \bar{\omega} \in (0,1)$	$\Delta(\Delta w(t > t_m)) > \Delta\eta$	*To collude*	*To collude*	*Increases*
	$\Delta(\Delta w(t > t_m)) < \Delta\eta$	*Not to collude*	*Not to collude*	*Decreases*
Increase "ω*", and* $\delta = \bar{\delta} \in \Re^+$.	$\omega > \omega^*$,	*Not to collude*	*Not to collude*	*Decreases*
	$\omega < \omega^*$	*To collude*	*To collude*	*Increases*

Source: Author's elaboration.
Note: The construction of chart-1, follows some, simplifications notes:

i. $\omega^* = \dfrac{\Delta w(.)}{\eta}$, $\omega^* = \dfrac{\Delta w(.)}{\alpha}$, are the values in which the players (official/landowner) are indifferent in respect to collude or not;
ii. It was used the case of the same bargaining power, (i.e., $x = \Delta w(.)$ and $\Delta x = \Delta(\Delta w(.))$);
iii. It was supposed the case: $\alpha = \eta$ and $\Delta\eta = \Delta\alpha$.

The chart shows that in the event that official and landowner agree to collude, the policies implemented by the government may be ineffective.

The situation investigated in this paper shows that the interactions of each player with one another create an incentive to perpetrate frauds, thus rendering ineffective government policies directed on fighting illegal deforestation. A new regulatory framework must be implemented in order to dissuade officials and landowner from colluding.

3 Conclusion

The presence of information asymmetry in the economy leads the individuals to try to profit from atypical situations. There is substantial research on corruption.

The controversy about the causes of deforestation is focalized on the landowners. However, information asymmetry, also, gives rise to other actors potentially culpable for illegal deforestation. Corruption is a factor that has not been given adequate attention by the policymakers.

In order to show how information asymmetry induces corrupt practices by low rank officials, a simultaneous game with complete/perfect information was modeled. It was used the static game because, the main objective of the paper was to highlight the existing gaps in the government policies. Given the dynamic structure of the game played between the landowner and official, and the importance of the credibility, the model desenvolved here capture just a picture of the extended agency's relationship between the Government and the IBAMA official. Thus, a further research in new approaches must be done in the future (e.g., the introduction of a dynamic relationship). Despite the simplicity, the model described here, fulfills perfectly the aims of the paper.

The paper departs from the standard deforestation theories, by assuming the corruption issue, it gives new and important insight about the consequence of the actual policies adopted by the Government. The model shows that there is an equilibrium in which the dominant strategy for the official and the landowner is to collude. The implication is that the policy of increased surveillance may be rendered ineffective.

One of the most provocative results is that harsher policies aiming the landowners may backfire, increasing illegal deforestation. Information asymmetry provides incentives for collusion and criminal practices. It was shown that heavier penalties may lead to increased illegal deforestation because there are bigger incentives to collusion.

Auditing the reports is a necessary but not sufficient measure to check collusive practices. It must be complemented by other provisions, like the effective punishment of corruption and heavier fines.

This paper advocates that the actual relationship between government and IBAMA officials has to be modified in order to prevent collusive practices. Internal auditing must be implemented to discourage opportunist behavior, made possible by information asymmetry.

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