A Game Theoretical Approach to the Balloon Effect

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November 15 2017

The balloon effect is a major criticism of U.S crime policies. The scenario occurs when investments in criminal enforcement in one area only shift crime to another, resulting in marginal long-run changes in total crime. The most notable example is United States' Plan Colombia, which spent billions of dollars to combat drug cartels, only to relocate drug production from Colombia to Peru and Bolivia without notable changes in the supply of narcotics. To address the balloon effect, this paper uses Gary Becker's rational theory of crime to provide a game-theoretical approach to mathematically define incentives of criminals and governments of an area. This paper first analyzes the rational competitive nature among governments when facing the threat of crime. Then it considers a potential intermediary to find a cooperative equilibrium among the governments.

Key Words: Crime, Balloon Effect, Game Theory, Becker's Crime Model

*Special acknowledgments to Sean Crockett, who helped provided invaluable feedback throughout this paper. Without him, this research would not have been possible.

1 Introduction

The balloon effect is often used to describe the movement of crime across different regions. When a balloon is pushed on one side, the air relocates itself to the other. In the same way, government investments in criminal enforcement reduce crime in one area, only to have it reappear in another. The investments only shift crime and do little to reduce it, resulting in a poor allocation of resources. This scenario is especially apparent in the war against drugs among the governments of South America and drug cartels. For example, Plan Colombia, a multi-billion dollar project designed to reduce drug production and trafficking in Colombia, only relocated drug production into Peru and Bolivia without changes in drug supply into the United States (Veillette 2005). Understanding the balloon effect can further the understanding of the dynamics behind the movement of crime and provide a new framework to create better policies to address crime not as isolated incidents (as many economists had already done), but as a general entity.

Understanding this scenario requires analyzing the incentives of governments and a criminal. This paper uses basic ideas of Becker's crime model to analyze the balloon effect in a game theoretical framework. Becker's model asserts that criminals and governments weight the costs and benefits of crime when deciding their choices. As a criminal increases his crime level, his payoff increases, yet the probability of getting caught also increases, forcing him to weigh these two factors to decide on his level of crime. On the other hand, the government has to weigh the costs of crime and the costs of enforcing crime. While increasing enforcement may decrease crime, it also increases the cost of enforcement. The government must find the optimal enforcement level to minimize its loses.

This paper establishes a model to help understand the balloon effect. It first reviews and interprets a one-shot game with only one government and one criminal by solving for a Nash Equilibrium. Then the paper extends that model to an arbitrary number of governments and one criminal. This model considers four factors (the cost per unit of enforcement, the distaste for crime, criminal biases, and enforcement constraints) and their influence on the model. Analyzing the dynamics between those parameters provide counter-intuitive results that others may have missed. Then the paper uses these parameters to better understand how and why the balloon effect appears in the game and from Plan Colombia. Furthermore, it considers involving an intermediary government to better address the balloon effect through a cooperative approach.

2 Review of Game Theory

For those familiar with the basic idea of game theory, this section may be skipped. Otherwise, a review of game theory is recommended to understand the model. However, keep in mind that this is not a comprehensive review.

Game theory is a branch of economics that analyzes the interaction between two or more players who maximize their individual benefits. In a one-shot game, each player p_i has a strategy profile S_i from which he will select a strategy s_i. Simultaneously and independently, all players select a strategy to commit to in a game. The game requires that each player is rational, meaning the selected strategies maximize his payoffs. In addition, each fact F is common knowledge among the players, meaning each player know F, each player know that others know F, and each player knows that every other player know F, and so on. Under these premises, it is possible to solve for the solution concepts, the theories of how games should be played, by evoking an equilibrium in which all players play a strategy that is irrational to deviate from.

To find that equilibrium, first search for the best responses for each player. Informally, a best response for a player p_i is a strategy that yields the greatest expected payoff against a certain belief, which is an assessment about the strategies of all other players p_{-i} in the game. In other words, a best response is the best strategy for player p_i to play in response to each strategy that all the other players p_{-i} play.

The Nash Equilibrium can be found by having each player coordinate on strategies that are best responding to each others' strategies. At this set of strategies, no players have an incentive to deviate from their chosen strategy because each is playing their best response to optimize their payoffs. A pure Nash Equilibrium occurs when players play the strategies with absolute certainty. A mixed-strategy Nash Equilibrium involves a probability distribution over possible strategies.

It is important to concede the pitfalls of game theory. Because game theory is the analysis of how players should act, it does not necessarily provide insight into how players will act if they face the scenarios in real life. In addition, assumptions such as common knowledge and rationality can be unrealistic in the real world. But there is experimental evidence to support that that people do play rationally in many games to a certain extent (Levin 2006). Furthermore, game theory can, at the very least, offer suggestions to how players should act to best maximize their gains. Using conclusions from the game can provide unique insights into the particular issue that the game represents.

3 A One Government Game

Before the balloon effect can be addressed with an arbitrary number of governments, it is helpful to understand a one-shot game between one government and the criminal using two payoff equations established by Joel Watson. Simultaneously and independently, government g_1 selects a law enforcement level from his strategy profile $x \geq 0$ while criminal C selects a crime level $y \geq 0$.

First, consider the expected payoff for g_1.

$$U_{g_1}(x, y) = -xc - \frac{y^2}{x} \tag{3.1}$$

The cost of paying for total enforcement $-xc$ is a linear function of the enforcement level, where c is the cost per unit of enforcement. $\frac{y^2}{x}$ is the negative effects of crime in the government. The crime effect y^2 indicates that crime is synergistic with itself, as the second order derivative with respect to the crime level is positive, while x acts a dilution effect on the crime, meaning government enforcement is able to mitigate the consequences of crime. Note that the crime effort is a degree higher than government enforcement and that there is only one local maximum for the payoff function with respect to enforcement x.

Before solving for the Nash Equilibrium, it is necessary to find the best responses of the government for all possible beliefs of the actions of the criminal, which is also called the best response function. Take the partial derivative of the payoff equation with respect to the level of enforcement to find optimal x^* with relation to every possible crime levels. Using that, the best response function BR is given.

$$\frac{\partial U_{g_1}}{\partial x} = -c + \frac{y^2}{x^2} \tag{3.2}$$

$$x* = \frac{y}{\sqrt{c}} \tag{3.3}$$

$$BR_{g_1}(y) = \frac{y}{\sqrt{c}} \tag{3.4}$$

Not surprisingly from equation 3.4, as the criminal's crime level increases, the enforcement level also increases. That and equation 3.1 implies that as crime level increases, the government's payoff depends more on the cost of crime than the cost of enforcement. As a result, the government is willing to increase enforcement to exchange an increase the cost of enforcement for a greater decrease in the cost of crime.

The expected payoff of the criminal is:

$$U_C(x,y) = \frac{\sqrt{y}}{1+xy} \tag{3.5}$$

The utility for the criminal $\sqrt{y}$ has a negative second order derivative to represent a marginally diminishing utility from crime. The expected payoff is that utility multiplied by the probability that the criminal evades capture, $\frac{1}{1+xy}$. The criminal weights the utility of crime and the probability of arrest to determine its optimal crime activity. Note that this function also has only one local maximum. Take the partial derivative for the payoff functions of the criminal with respect to y to find the best response function.

$$\frac{\partial U_C}{\partial y} = \frac{1-xy}{2\sqrt{y}(1+xy)} \tag{3.6}$$

$$y* = \frac{1}{x} \tag{3.7}$$

$$BR_C(x) = \frac{1}{x} \tag{3.8}$$

From equation 3.8, as the government enforcement increases, the crime level must decrease. This implies that as the enforcement increases, the expected payoff for the criminal depends more on the probability of evading capture than the utility of crime. Therefore, crime level must decrease.

Finding the intersection of the two best response functions lead to a single Nash Equilibrium. Using equations 3.4 and 3.8, the optimal enforcement $x*$ and optimal $y*$ in terms of the c is:

$$x^* = \frac{1}{c^{\frac{1}{4}}} \tag{3.9}$$

$$y^* = c^{\frac{1}{4}} \tag{3.10}$$

From equation 3.10, the greater the cost per unit of enforcement c, the greater the crime level y. Intuitively, it may seem that they are loosely related. But it must be true because at equilibrium, the marginal cost of enforcement must equal the marginal cost of crime for every change in enforcement. When the cost per enforcement increases, the more the government's payoff depends on the cost of enforcement than the cost of crime, giving the criminal more leverage to commit more crime. Another way to interpret this is that there is more crime when the government is less able to pay for it (which is when the cost per unit of enforcement increases). For a similar reason, from equation 3.9, the greater the c, the less enforcement there is.

It is also important to note the inverse relationship between government enforcement and crime level. Any changes in the parameters of government g_1 will change enforcement while producing the opposite change of crime for the criminal. For example, increases in c will decrease enforcement (equation 3.9) and increase crime level (equation 3.10).

From equation 3.10, it is also interesting that it is impossible to completely eliminate crime and that reducing crime beyond a certain point is not optimal unless the cost per unit of enforcement is unrealistically 0.

For the criminal, the probability of evading capture ($\frac{1}{1+xy}$) is always 50% because $x* = \frac{1}{y*}$ from equation 3.8. So no matter how much the government increases its enforcement, the criminal will always counter by reducing their crime rate, and by extension, the probability of evading capture, until the equilibrium at 50%

Subsituting equations 3.9 and 3.10 in equations 3.1and 3.5, provide the payoffs for both the government and the criminal.

$$U_{g_1} = -2c^{\frac{3}{4}} \tag{3.11}$$

$$U_C = \frac{c^{\frac{1}{8}}}{2} \tag{3.12}$$

From these payoff functions, the criminal always wins (always has a positive payoff) and the government always loses (always has a negative payoff). Also, note that as c increases, the payoffs for the government always decreases while the payoffs for the criminal always increases because decreasing c allows for more crime.

This simple case already provides very interesting interpretations. Though these interpretations do not yet directly address the balloon effect because they do not involve multiple governments, the basic set up does help establish the dynamics between the government and the criminal, as the analysis above still holds true for an arbitrary number of governments.

4 Generalizing to an Arbitrary Government Game

The one government game can be extended into an arbitrary n-government game. Let n be the set of governments $g_1, g_2, ..., g_n$ in the game. The governments are in competition to reduce crime, and by extension, decrease their own negative effects of crime from a single criminal. Each government has a different function to represent their payoffs, but the functions all have the basic structure. Each g_i picks an enforcement level $x_i \geq 0$ and the criminal picks a crime level $y_i \geq 0$ to commit to in each government and a probability p_i that the criminal will enter each government[1]. The expected payoff for each government is:

$$U_{g_i}(\{x_i \mid i \in n\}, \{y_i \mid i \in n\}) = -\frac{p_i d_i y_i^2}{x_i} - c_i x_i, \forall g_i \in n \tag{4.1}$$

This equation recognizes that countries are affected differently by the distaste for crime d_i and have different costs per unit of enforcement c_i. The probability p_i will depend on the enforcement level of all the other governments x_{-i} and the crime level the criminal will place in each government y_{-i}. The expected negative effects of crime is the probability that the cartel will be in that certain area multiplied by the negative effects. Notice that this probability will not affect the total cost of enforcing crime $-c_i x_i$ because it is certain that each government will face the enforcement cost it plays.

The expected payoff for the criminal is:

$$U_c(\{x_i \mid i \in n\}, \{y_i \mid i \in n\}) = \sum_{i=1}^{n} \frac{p_i b_i \sqrt{y_i}}{1 + x_i y_i} \tag{4.2}$$

The criminal's expected payoff is the sum of payoffs it receives by placing a probability p_i of entering each government, multiplied by payoff from the allocated crime and enforcement level in each government. The b_i signifies the criminal's bias for one government over the others, if the criminal has a greater bias for a government, its payoff from entering that government is amplified by the factor b_i.

The solution process for the Nash Equilibrium is similar to the solution for a one government game. But it is necessary in this scenario to find the value of the probability of the criminal entering each government in terms of only the parameters. To find the mixed strategy Nash Equilibrium of this scenario, first solve for the best responses for the governments' enforcement level and the criminal's crime level in each government. Keep in mind that the equations and the derivations are very similar to that of the one government game.

From equation 4.1, take $\frac{\partial U_i}{\partial x_i}$ for each payoff equation of each government. Set them equal to 0 to find the best response functions.

[1] As it appears, this a mixed strategy game (there is a probability distribution) rather than a pure strategy game (the criminal will enter only one country with certainty). To see why this is true, first assume there is a pure Nash Equilibrium. Then the criminal only chooses one government g_i to inhabit with absolute certainty. However, if a criminal were to have that choice, then all the other governments g_{-i} will play no enforcement because they know that the criminal will not enter and that there is no crime, therefore no need for enforcement. But then it is irrational for the criminal to chose the government it just chose because it will always benefit more from choosing a government with zero enforcement than with a government with some enforcement. This holds true for all possible enforcement levels. Therefore, a pure Nash Equilibrium does not exist and the scenario requires a mixed strategy equilibrium.

$$BR_{g_i} = (\frac{d_i p_i}{c_i})^{1/2} y_i, \forall g_i \in n \tag{4.3}$$

From equation 4.2, take $\frac{\partial U_c}{\partial y_i}$ and set it equal to 0 to find the best response of the criminal to each government enforcement.

$$BR_c = \frac{1}{x_i} \tag{4.4}$$

Using equations 4.3 and 4.4, find their intersection to solve for the mixed strategy Nash Equilibrium. The optimal $x*$ and $y*$ for each government $g_i \in n$ are:

$$x_i^* = (\frac{d_i p_i}{c_i})^{1/4} \tag{4.5}$$

$$y_i^* = (\frac{c_i}{d_i p_i})^{1/4} \tag{4.6}$$

Next, solve for the probability p_i that the criminal will enter each government in terms of the parameters b_i, c_i, and d_i. In a mixed strategy game, the players who choose the probability distribution must be indifferent between all their choices. Therefore, the payoffs (not considering the probability) for the criminal entering each government must be the same.

$$\frac{b_1\sqrt{y_1}}{1 + x_1 y_1} = \frac{b_2\sqrt{y_2}}{1 + x_2 y_2} = ... \ = \frac{b_n\sqrt{y_n}}{1 + x_n y_n} \tag{4.7}$$

Using this, it is possible to find the values of all p_i for each $g_i \in n$.[2]

$$p_i = \frac{b_i^8 c_i}{d_i} \alpha \tag{4.8}$$

$$\alpha = \frac{1}{\sum_{i=1}^{n} \frac{b_i^8 c_i}{d_i}} \tag{4.9}$$

Using equations 4.5, 4.6, and 4.8, the values of x^* and y^* in terms of the parameters for all $g_i \in n$ are:

$$x_i^* = b_i^2 \alpha^{1/4} \tag{4.10}$$

$$y_i^* = \frac{1}{b_i^2 \alpha^{1/4}} \tag{4.11}$$

The equations 4.1, 4.2, 4.10, and 4.11 are used to find the payoffs at equilibrium U_i and

[2] See derivation in the appendix.

U_c for all $g_i \in n$.

$$U_{g_i} = -2c_i b_i^2 \alpha^{1/4} \tag{4.12}$$

$$U_c = \frac{1}{2}\alpha^{\frac{7}{8}} \sum_{i=1}^{n} b_i^{\frac{15}{8}} \frac{c_i}{d_i} \tag{4.13}$$

Part of understanding the balloon effect through this framework involves analyzing how parameters such as the distaste for crime d_i, the cost per enforcement c_i, and the bias for governments b_i influence the model. The results of the model provide very interesting and even counter-intuitive conclusions.

Consider the influences of the number of governments in the game. As the number of players increase, the value of α, an entity that describes the aggregate effects of all the parameters on the governments and the criminal, decreases (equation 4.9). Equivalently speaking, as the constants or number of constants b_{-i}, c_{-i}, and d_{-i} increases, the influence of one individual b_i, c_i, or c_i on x_{-i}, y_{-i}, $U_{g_{-i}}$, and U_c decreases. This is not surprising because more governments spread the probability distribution thinner, reducing possible threats of crime (and by extension, the influence on the threat of crime) to an individual government. For criminals, as seen at equation 4.13, as there are more government, the criminal's payoff increases without bounds even as the probability distribution spreads thinner. This is because as the probability distribution thins, the less probability of crime that each government faces. This reduces the expected crime that the government faces ($y_i p_i$), which allows for less enforcement, and thus more crime. In addition, from equations 4.12 and 4.13, more governments also benefit the government, as it decreases costs for the government while increasing payoffs for the criminal.

Consider the influences of the distaste for crime d_i. As d_i decreases, p_i decreases (equation 4.8) and crime level increases (equation 4.11. So it seems that the more the government hates crime, the less crime there is, which is quite counter-intuitive. But this can be explained by equation 4.5 that the distaste for crime causes an increase in enforcement. From equation 4.12, this decreases the payoff for the government, even as there's less crime and less chance that the criminal will enter. But this actually to be expected, as the distaste for crime increases, the more enforcement the government needs (equation 4.5). It appears that in this model, the increase of the negative effects of cost of enforcement out weights the decrease in crime and the decreased in the probability that a criminal will enter.

Consider the scenario where the criminals have no preferences between one government over the other ($b_i = 1, \forall i \in \{1, 2, ..., n\}$). Intuitively, the distaste for crime d_i should be a variable that causes a criminal to have different crime levels in each government. Moreover, it is expected that the ability to pay for crime c_i should also be a reason for the criminal to differentiate one government from another. However, from equation 4.10, that is not the case. Notice that if the criminal has no preferences over a certain government over the other ($b_i = 1$), then all the government plays the same level of enforcement (namely $\alpha^{\frac{1}{4}}$) and criminals play the same level of crime over all governments ($\alpha^{-\frac{1}{4}}$), regardless of the cost per unit of enforcement c_i and the distaste for crime d_i. But a careful analysis shows that though counter-intuitive, it must hold true. For a mixed equilibrium to exist, the criminal must be indifferent between choosing the governments, forcing the governments to have the same enforcement. However, that does not mean that the criminal treats the governments the same way even if its criminal activity is the same. From equation 4.8, the differences in the parameters b_i, c_i, and d_i manifests itself in p_i, the probability that the criminal will choose one government.

Now consider the scenario where criminal bias b_i does matter. Even though attributes of the government, such as d_i and c_i, does not set itself apart from other governments, b_i does (equation 4.10). Because the criminal must directly take into account b_i, the criminal needs to be indifferent between choosing any of the government, forcing enforcement to match up to preferences. As b_i increases, the crime level decreases. This is very counter-intuitive because when bias increases in one government, one would expect that there is more crime because the payoffs of crime is amplified by b_i. However, as b_i increases, enforcement increases (equation 4.10) because the government understands that there is a greater potential for the criminal to enter the government (greater p_i from equation 4.8), increasing enforcement (equation 4.5), which forces the crime level to decrease (equation 4.6). Yet from equation 4.13, the payoff for the criminal also increases, meaning the increase of payoff from the increase in the probability of entering that government outweighs the decrease in the payoff from decreased crime level.

5 Consideration of a Constraint

In the real world, some governments simply do not have the infrastructure to employ their optimal enforcement. For example, the governments may not have the ability to borrow money from other countries or do not have the necessary equipment to deal with crime. This may be due to lack of a firm political structure or stable military. Or, the country may simply lack experienced soldiers, police, equipment, hackers, information, et cetera. Whatever the case may be, it is important to consider the scenario when there's a limitation of enforcement.

Let γ_i be the proportion of x^* that represents constraint, where $0 < \gamma_i < 1$. Governments with a constraint greater than or equal to the optimal enforcement level has a $\gamma_i = 1$. Then using equations 4.5 and 4.6, the optimal enforcement level, x_i and optimal crime level y_i is:

$$x_i^* = \gamma_i(\frac{d_i p_i}{c_i})^{1/4}, \forall i \in n \tag{5.1}$$

$$y_i^* = \frac{1}{\gamma_i}(\frac{c_i}{d_i p_i})^{1/4}, \forall i \in n \tag{5.2}$$

It is important to note that a smaller γ_i does not necessarily imply a greater physical constraint on the enforcement because the initial optimal enforcement may be higher. Also, the idea of constraint should not be taken literally. γ_i is itself not a boundary; it is a proportion that exactly aligns to force the optimal enforcement to meet that boundary.

Already, it is apparent that as γ_i decreases (as the constraint is greater), the less enforcement that government g_i can play and the more crime the criminal will place in that government. This makes sense because the optimal enforcement level in some ways acts as a deterrent to crime. The acknowledgment of a lower enforcement level allows the criminal to increase his crime.

These constraints can be used to solve for the probability that the criminal will enter each government p_i by using similar steps in the appendix. The resulting probability for all $g_i \in n$:

$$p_i = \frac{b_i^8 c_i}{d_i \gamma_i}\beta \tag{5.3}$$

$$\beta = \frac{1}{\sum_{i=1}^{n} \frac{b_i^8 c_i}{d_i}\gamma_i^4} \tag{5.4}$$

Some things to note include the fact that as γ_i decreases, the probability that the criminal will enter that government will increase. But unsurprisingly, β, an entity that describes the aggregate influence of the choices of the criminals and governments as a whole with constraint, is affected by the constraint.

Then the value of x_i^* and y_i^* can be found using equations 5.1, 5.2, and 5.3.

$$x_i^* = b_i^2 \beta^{1/4} \tag{5.5}$$

$$y_i^* = \frac{1}{b_i^2 \beta^{1/4}} \tag{5.6}$$

$$U_{g_i} = -b_i c_i^2 \beta^{\frac{1}{4}} (1 + \frac{1}{\gamma_i^4}) \tag{5.7}$$

Interestingly, the constraint proportion γ_i does not set the optimal enforcement level apart from the other governments. This is expected, however, because γ_i is simply an adjustment of the optimal enforcement. If the original optimal enforcement does not dictate a difference in enforcement level, then neither should its adjustment.

6 The Balloon Effect

Part of understanding the balloon effect first comes from understanding the dynamics among the competitive governments and a single criminal. The second part is to directly relate the scenario with the idea of the balloon effect.

Just to recap, the balloon effect occurs when an outside government, the intermediary, invests in enforcement in a government, hoping to reduce the crime level in that area. Though that may be achieved, the end result may just be a shift in crime from one area to another, resulting in marginal changes in total crime levels instead of drastically reducing crime.

As seen from the model, there is an optimal enforcement level x^* that is trying to be achieved, except that there may be a constraint that prevents the government from playing that enforcement. An outside government G, which suffer from negative externalities of crime in the governments, may invest resources to help the governments approach their equilibrium level. That may include investing resources to change the distaste for crime d_i, the cost per enforcement c_i, criminal bias b_i, or the constraint proportion γ_i. After the changes, the probability of entering that country p_i will decrease (equation 5.3). However, the total probability is constant, which forces the probability of governments g_{-i} to increase. Interestingly enough, crime levels for governments g_{-i} decreases (equation 5.6) while enforcement increases (equation 5.5). However, there is a negative net result, as the payoffs of governments g_{-i} decreases (equation 5.7). Therefore, even as total crime is decreasing, the probability is shifted around. Helping one government produces a negative externality for the other governments. The more governments in the game, the more the total negative externality.

One of the most notable examples of the balloon effect is Plan Columbia. By 2008, the U.S. contribution to Plan Columbia for military purposes has totaled to 4.8 billion dollars. The money was spent in providing equipment and training the Colombian army, air force, and the navy to interdict drug transportation (United States GAO 2008). Relating to the model of this paper, it appears that the U.S., the intermediary G, attempts to reduce the cost of enforcement c_i and increase the proportion constraint γ_i, which reduces the probability that crime will take place in Colombia. But despite the efforts of the plan, there seem to be no notable changes in price and availability of cocaine and heroin in the U.S. (Veillette 2005). But there has been a significant reduction in crime in Colombia from the efforts, indicating that drug production shifted elsewhere (Bachelet 2005). In fact, there is evidence to suggest that cocaine production and cultivation shifted to Bolivia and Peru, which had declining drug production until Plan Columbia had been enacted (Bagley 2012). This gives evidence that Plan Colombia ended up increasing the probability that crime will take place in other countries.

7 Cooperation Among Governments

There is a way for the governments to cooperate to benefit all the governments as a whole. Instead of focusing individual payoffs, the governments can establish a coalition to choose the most efficient strategy, the strategy that minimizes total costs. However, this scenario will produce a more efficient result only when all the parameters (b_i, c_i, d_i, γ_i) are adjusted for this purpose. When they are not, it may not be necessarily true that this cooperative approach will produce a greater payoff.

In the coalition, governments establish a set enforcement that every government must commit to and force the probability to be evenly distributed instead of letting the probability depend on the government's parameters. In the competitive game, all the governments also play the same enforcement level (when bias $b_i = 1$), but the governments suffer from inefficiencies and the threats of other governments and the criminal, forcing the governments to play more inefficient strategies. In the coalition, governments are freed from such threats because each is guaranteed to play a prescribed strategy free from the influences of the criminal and other governments. Ideally, the governments desire to form a grand coalition, where all governments are in the coalition. Elsewise, governments who would not gain by joining the coalition would set their own optimal enforcement that would be higher than the enforcement set by the coalition, forcing crime away from those governments and into the governments in the coalition. The only way a grand coalition can occur is to introduce an intermediary who exactly subsidizes the opportunity cost of joining the coalition instead of working alone.

If a grand coalition occurs, the leader must also ensure that the governments in the coalition will not cheat. Governments will have an incentive to add an epsilon ε amount to shift probability of crime down to 0 and increase their payoffs. If that happens, the governments revert back to the competitive game. Therefore, the leader must enforce a punishment necessary to deter governments from following their incentives.

To find the optimal enforcement to maximize the total payoffs of all the countries, first assume that all d_i and c_i are the same, $b_i = 1$ and $\gamma_i = 1$. Ideally, the countries want the same enforcement, forcing the probabilities of the criminal's crime level placement to be equal. Then the probability that the criminal will enter each government is $\frac{1}{n}$. The total payoff for all the governments is:

$$U_T = -\frac{\sum d_i p_i}{x^3} - x \sum c_i \tag{7.1}$$

$$U_T = -n(\frac{d}{nx^3} + cx) \tag{7.2}$$

Take the partial derivative with respect to x and solve for the optimal $x*$.

$$x* = (\frac{d}{c})^{\frac{1}{4}} (\frac{3}{n})^{\frac{1}{4}} \tag{7.3}$$

Then the total payoff is approximately:

$$U_T \approx -1.754 d^{\frac{1}{4}} c^{\frac{3}{4}} n^{\frac{3}{4}} \tag{7.4}$$

Compared to the total payoffs in the competitive scenario, the cooperative equilibrium is more efficient.

So by establishing a coalition where all the governments play the same enforcement, the intermediary is able to reduce the costs of crime. This could be the first step towards better approaching the balloon effect. In a more realistic condition, where parameters are different, it is expected that the probabilities or the enforcement level may be different, but considering a coalition would still reduce inefficiencies. The second step is to have the intermediary subsidize all the governments appropriately instead of simply focusing on one government to reduce the negative effects of the balloon effect. Though this second step isn't discussed in this paper, it is hoped that it will eventually be analyzed.

8 Conclusion

An analysis of the interactions between rational governments and criminals provide insight into understanding the motivations behind the choices that each player makes. Using game theory, a mixed-strategy Nash equilibrium is solved to understand the dynamics of all the players. In addition, the model helps readers understand the influences of major parameters, including the distaste for crime, the cost per enforcement, criminal bias, and enforcement constraint. Using these insights, it is possible to better address the balloon effect through the use of an intermediary, who can either approach the problem in a competitive or a cooperative framework.

Though game theory may have unrealistic assumptions, such as the idea of common knowledge and rationality of all players, game theory can provide a framework to better understand the dynamics of crime and the balloon effect. As shown in the model, some results proved to be so counter-intuitive that they may be completely missed by those who had analyzed the dynamics of crime before. These results may be used to create suggestions to address crime as a whole, instead of simply as isolated incidents. As a result, economics may rethink the way they approach crime. In Plan Colombia, the U.S. invested billions of dollars to address drug production in Colombia, only to find that drug production moved elsewhere. The U.S. was too focused on one country, allowing their operation to fall short on the pitfalls of the balloon effect. Using this model can help economics reconsider future policies for addressing the war on drugs or even crime in general.

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9 Appendix

This section will contain the derivation of the probability distribution. Given the properties of a mixed strategy, the criminal is indifferent between choosing any of the governments. Therefore:

$$\frac{b_1\sqrt{y_1}}{1+x_1y_1} = \frac{b_2\sqrt{y_2}}{1+x_2y_2} = ... \;\; = \frac{b_n\sqrt{y_n}}{1+x_ny_n} \tag{9.1}$$

Because $y_i = \frac{1}{x_i}$, equation 9.1 simplifies to:

$$b_1\sqrt{y_1} = b_2\sqrt{y_2} = ... = b_n\sqrt{y_n} \tag{9.2}$$

Since $y_i = (\frac{b_i}{a_ip_i})^{1/4}$, equation 9.2 is equivalent to:

$$b_1^8\frac{c_1}{d_1p_1} = b_2^8\frac{c_2}{d_2p_2} = ... = b_n^8\frac{c_n}{d_np_n} \tag{9.3}$$

Which can be written as:

$$\frac{\frac{b_1^8c_1}{d_1}}{p_1} = \frac{\frac{b_2^8c_2}{d_2}}{p_2} = ... = \frac{\frac{b_n^8c_n}{d_n}}{p_n} \tag{9.4}$$

To find $p_i, \forall g_i \in n$, first let:

$$\frac{1}{\alpha} = \frac{1}{\alpha} = ...\frac{1}{\alpha}; \text{for n times} \tag{9.5}$$

Equivalently from 9.5:

$$\frac{\frac{b_1^8c_1}{d_1}}{\frac{b_1^8c_1}{d_1}\alpha} = \frac{\frac{b_2^8c_2}{d_2}}{\frac{b_2^8c_2}{d_2}\alpha} = ... = \frac{\frac{b_n^8c_n}{d_n}}{\frac{b_n^8c_n}{d_n}\alpha} \tag{9.6}$$

Then from equation 9.4 and 9.6:

$$p_i = \frac{b_i^8c_i}{d_i}\alpha \tag{9.7}$$

Then taking the summation of $p_1, p_2, ..., p_n$ from 9.7,

$$\sum_{i=1}^{n} p_i = \sum_{i=1}^{n} \frac{b_i^8c_i}{d_i}\alpha \tag{9.8}$$

Knowing that $\sum_{i=1}^{n} p_i = 1$ allows for the solution of α.

$$1 = \sum_{i=1}^{n} \frac{b_i^8c_i}{d_i}k \tag{9.9}$$

$$\alpha = \frac{1}{\sum_{i=1}^{n} \frac{b_i^8 c_i}{d_i}} \tag{9.10}$$

Therefore, from equation 9.7:

$$p_i = \alpha \frac{b_i^8 c_i}{d_i} \tag{9.11}$$