Game Theory and the Mexican Drug War

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Fall 2011

In Partial Fulfillment of

Stat 4395-Senior Project

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Abstract

Throughout history, a total of eight game theorists have won the Nobel Memorial Prize in Economics. Most recently, Robert Aumann, from the University of Jerusalem, and Thomas Schelling of the University of Maryland and Harvard University won this prestigious award for “having enhanced our understanding of conflict and cooperation through game theory analysis” (nobelprize.org). Modern applications of game theory are enabling humans to decipher complex models in areas such as finance, biology, and even international conflicts.

This analysis will apply ideas of game theory to a simulated model of the current War on Drugs in Mexico to determine the optimal strategy for the three players involved: Mexican Government, Cartel I, and Cartel II. In addition, the analysis will further explore the concept of game theory by examining cartel cooperation and conflict. Finally, the analysis will answer the questions required to determine what factors might motivate the two cartels to form a strategic alliance or fight each other.
Introduction

The word 'game' might conjure thoughts of one or more individuals enjoying a recreational activity such as volleyball or golf. The primary objective in each of these leisurely activities is to win. Merriam-Webster defines 'win' as "to gain victory in a contest." Gaining victory could translate to having the most points in volleyball, or having the fewest number of strokes as is the case in golf. Victory might manifest itself in running the fastest time if participating in a marathon, or it might also be correctly filling in all the missing square in Sudoku. While individuals do play these types of games for recreational purposes, there is also a subset of people that analyze the ‘game’ for one purpose- to develop winning strategies. Hopefully, these strategies will maximize a player's payoff, i.e. having the highest score or the fastest time. For example, professional athletes are paid millions of dollars with the hope of having a winning season. In this scenario, athletes push their bodies to the limits and mentally prepare themselves for the opponent that awaits. Trainers, coaches, and coordinators analyze their opponents via film footage and statistics hoping to discover potential weaknesses that can be exploited. Whether it’s an individual or a professional sports team, strategies can be derived through careful analysis to increase the odds of winning.

On the other hand, there are major corporations around the world seeking to maximize their profits at any given time. Interestingly enough, there is a beneficial strategy for competing entities to cooperate in order for profits to increase. One real life scenario is that of Proctor & Gamble and Unilever. P&G is an American Fortune 500 company famously knows for its household cleaning products as well as for introducing fluoride-based toothpaste and disposable diapers. Unilever is a European based billion dollar company with such brands as Axe, Dove, Lipton, Slim Fast, and Calvin Klein. Boyes claims in *The New Managerial Economics*, that P&G and Unilever have agreed not to 'blind side' each other by switching marketing strategies without prior notification. Before this agreement, both of these companies were in a stalemate in regards to
global competition with each other. P&G and Unilever feel this is the best strategy at the moment to keep profit margins high. However, agreements among other corporations such as OPEC (Organization of Petroleum Exporting Countries) have resulted in disastrous consequences not only for the profits of members of this organization, but also for the world. There is a branch of mathematics that can attempt to model real world situations such as these with the hope of obtaining successful strategies.

**What is Game Theory?**

Hamdy Taha explains that "game theory deals with the decision situations in which two rational opponents with conflicting objectives are vying to outdo one another." Thomas J. Webster defines a game as "any situation in which the final outcome depends on decision makers' strategic choices" and a player as "a decision maker". One of the most crucial parts of game theory is that the players must be rational, or seeking to optimize their payoffs in any given game. In other words, the decision makers should actively seek strategies that will be of most benefit to them. Let's look at an example.

Let's pretend Jack and Jill are playing a game of tic-tac-toe with Jack playing crosses and Jill playing circles. Jack just moved, and it's currently Jill's turn to decide what to do next.
If Jill is a rational player and does not want to lose on the following turn, she must block Jack's potential game ender by playing the following move depicted in the graph.

![Game Board Diagram]

Clearly, Jill has played the best move, and can now consequently seek a strategy to win the game. We will now delve into some strategies that game theory has to offer in helping to assess different strategies.

**The Nash Equilibrium**

John Forbes Nash Jr. is a Nobel Prize winning Mathematician who was portrayed by Russell Crowe in *A Beautiful Mind*. While at Princeton University pursuing his doctorate in Mathematics, John Nash developed what would be known as the Nash Equilibrium. The famous result originated in his 1950 dissertation titled *Non-Cooperative Games* which would earn him a Nobel Prize in Economics in 1994, exactly forty four years later. The Nash Equilibrium is a crucial part of game theory, and will be the primary tool that is used to help model and assess strategies here. Webster defines the Nash Equilibrium as follows, "When each player adopts a strategy that is the best response to the strategies adopted by the rivals. A strategy is a Nash Equilibrium when no player can improve his or her payoff by switching strategies". Let's consider the following scenario.
We have two rival companies, Firm A and Firm B, that both sell widgets. Each rival has one of two strategies. They can choose to sell the widgets at a high price or a low price.

The chart above is an example of a payoff matrix. The first monetary payoff in a cell relates to Firm A, and the second one relates to Firm B. If we look at both companies choosing to sell their widgets for a high price, each one will have a $3 million dollar payoff. However, if one firm chooses to sell high, while the other chooses to sell low, the firm who sells high will obtain $300,000 while the firm that sells low will gross $15 million. What would be a rational strategy for either firm to pursue here? The Nash Equilibrium can be used to assess this game.

Let's refer back to the definition of the Nash Equilibrium. The main part of the definition says that a particular strategy is a Nash Equilibrium when no player can improve his or payoff by switching strategies. Let's assess this game of selling widgets by taking the perspective of Firm A. First, we will assess the strategy of Firm A selling at a high price. If Firm A sells at a high price, Firm B can either sell at a high price also, or decide to sell at a low price. We will first analyze Firm B choosing to sell high, and then Firm B choosing to sell low.
Firm A (High Price) and Firm B (High Price) both get a payoff of $3 million

1. Can Firm A switch strategies to obtain a higher payoff while Firm B keeps the same strategy (High Price)?
2. Yes, if Firm B continues to sell high, then Firm A can choose to sell low and increase its payoff to $15 million while Firm B's payoff drops down to $300,000
3. Thus, Firm A (High Price) and Firm B (High Price) is not a Nash Equilibrium

Firm A (High Price) receives a payoff of $300,000 and Firm B (Low Price) receives a payoff of $15 million

1. Can Firm A switch strategies to obtain a higher payoff while Firm B keeps the same strategy (Low Price)?
2. Yes, if Firm B continues to sell low, then Firm A can choose to sell low and increase its payoff to $750,000 while Firm B's payoff drops down to $750,000
3. Thus, Firm A (High Price) and Firm B (Low Price) is not a Nash Equilibrium
4. In conclusion, the strategy profile (High Price) is not a Nash Equilibrium for Firm A, nor for Firm B because of symmetry in our matrix.
We now have one strategy profile left (Low Price, Low Price), and we must verify if this strategy is a Nash Equilibrium.

- Firm A (Low Price) and Firm B (Low Price) both get a payoff of $750,000
  1. Can Firm A switch strategies to obtain a higher payoff while Firm B keeps the same strategy (Low Price)?
  2. No, if Firm B continues to sell low, then Firm A can choose to sell high and decrease its payoff to $300,000 while Firm B's payoff increases to $15 million.
  3. Thus, Firm A (Low Price) and Firm B (Low Price) is a Nash Equilibrium

A Nash Equilibrium is important because it also referred to as a strictly dominant strategy equilibrium. In this scenario, Firm A and Firm B should choose the dominant strategy which is to sell low. This way, if both firms sell low, each one will get at least $750,000, and if one of the firms chooses to sell high, then the payoff increases to $15 million for the other firm.

The Prisoner's Dilemma

To further our understanding of how game theory will help with the current Mexican Drug War, another major concept must be understood. The Prisoner's Dilemma is a hypothetical incident developed by Albert J. Tucker in the 1950's. While there are many variations of this scenario, let us observe the following details for this example.

- Two suspects, Suspect A and Suspect B, have been apprehended by the police in regards to a robbery. Each of the suspects is separated into different holding areas without the ability to communicate with each other. The District Attorney talks with each suspect individually and offers each of them the following deal:
- 5 years if they both confess
- 0 years if A confesses and B does not
  (B gets 20 years) and vice versa
- 1 year if they both remain silent

By observing the matrix above, it seems that both suspects should remain silent to avoid serious charges and only serve 1 year in jail individually. Let's verify if this scenario is a Nash Equilibrium the same way we previously did.

- Prisoner A (Remain Silent) and Prisoner B (Remain Silent) both get a payoff of 1 year served behind bars

  1. Can Prisoner A switch strategies to obtain a higher payoff (lower sentence) while Prisoner B keeps the same strategy (Remain Silent)?
2. Yes, if Prisoner B continues to remain silent, then Prisoner A can choose to confess and increase his or her payoff (lowered sentence) to 0 years behind bars while Prisoner B’s payoff drops (increased sentence) goes up to 20 years.

3. Thus, Prisoner A (Remain Silent) and Prisoner B (Remain Silent) is not a Nash Equilibrium.

Consequently, remaining silent is not a dominant strategy for either player. We will show that 'confessing' is the dominant strategy.

- Prisoner A (Confess) and Prisoner B (Confess) both get a payoff of 5 years served
  1. Can Prisoner A switch strategies to obtain a higher payoff (lower sentence) while Prisoner B keeps the same strategy (Confess)?
  2. No, if Prisoner B continues to confess, then Prisoner A can choose to remain silent and decrease his or her payoff (increased sentence) to 20 years behind bars while Prisoner B’s payoff drops (decreased sentence) to 0 years served.
  3. Thus, Prisoner A (Confess) and Prisoner B (Confess) is a Nash Equilibrium.

The Prisoner's Dilemma demonstrates that both suspects should remain silent to receive the lowest sentence, but that the dominant strategy is to confess. Webster has described this dilemma as "a game in which it is in the best interest of all players to cooperate, but where each player has an incentive to adopt his or her dominant strategy." This game gives some insight into why it might be beneficial for some entities to betray each other if the payoff is irresistible.

Social scientists, philosophers, and psychologists have been fascinated by this scenario. In experiments conducted by Cooper, DeJong, Forsythe and Ross (1996), volunteers were asked to
play the prisoner’s dilemma 20 times against 20 different, unknown volunteers. In the first five rounds, players cooperated 43% of the time. However, in the last four rounds, players only cooperated 20% of the time. Various experiments have confirmed that confessing is the strictly dominant strategy in the Prisoner's Dilemma.

**Mexican Drug War Background**

The recent wave of violence attributed to the Mexican Drug War, began when newly elected Mexican President Felipe Calderon sent 65,000 troops to the state of Michoacan to eradicate drug violence on December 11, 2006. Calderon ran a huge campaign promising to alleviate Mexico from the systematic rule of drug cartels, but no one believed he would actually keep his promise once elected. Prior to Calderon taking office, there were rumors of significant corruption between cartel leaders and government officials. These back room deals consisted of official taking bribes to not pursue cartels, while the cartels would keep violence out of the public eye. However, once Calderon publicly denounced the cartels and actively pursued these criminals, the cartels would begin one of the deadliest battles in modern history.

**Drug War Statistics**

According to a cost benefit analysis from 1989-2000 done by Viridiana Rios, a PhD candidate in Inequality and Criminal Justice at Harvard University, Mexico has lost an average of 3.5 Billion USD per year due to illegal drug activity. These losses primarily stem from productivity losses, violence, and corruption. In regards to productivity losses, the World Drug Report 2007, stated that in a study involving Egypt, Mexico, Nambia, and Poland, it was found that substance abusers have 2-4 times more accidents at work than other employees and are absent 2-3 times more often. Furthermore, the cost of incarceration and treatment of addicts further compounds the situation.
The cost benefit analysis performed by Rios clearly illustrates the path of how drug traffic costs have been steadily increasing over the years to eradicate any positive economic impact that was initially felt in the 80's. More competition from rival factions, stricter laws by both the Mexican and American Governments, and suspicion that up to 50% of cartel leaders profits go overseas (Sarmiento 1991) have decreased most of the capital flows to Mexico. However, while the costs for the government have increased, there is evidence that drug profits have also decreased for the players in the lucrative drug traffic market.
From 1985-2000, Mexican cartels have earned an average of 6.16 Billion USD per year. While the overall margins have fallen since the early 90's, this industry is billion dollar business that ranks as one of the top 100 business in Mexico and easily overshadows the profits of American Express Mexico (Rios). However, while competition has decreased the price of drugs and overall profits, it has significantly increased the amount of murders in Mexico.

According to Icasualties.org, an independent website that compiles data from the Multi-National Force in Iraq, the US Department of Defense, The British Ministry Defence, and other authoritative sources, there have been a total of 4,801 Coalition Military fatalities from 2003-2011 during Operation Iraqi Freedom. During Operation Enduring Freedom in Afghanistan, 2,823 coalition Military fatalities have been recorded in the same time frame. Mexico had 15,273 murders directly related to drug violence in 2010 alone. In 2009, there were 9,614 murders directly attributed to drug violence. This is an increase of approximately 58.9% in only a year.
The map above shows the total deaths for 2010. It is easily seen that most killings are taking place in the southern border with Central America. The most likely scenario is that cartels are fighting over drug routes that initiate in Columbia, cross through the heart of Mexico, and end up the United States. The Mexican Government has a significant problem on its hands. It is losing billions of dollars per year from drug traffic, it is losing its citizens to drug violence, and it is losing foreign investment for fear of drug violence and retaliation (Rios). Game theory will be used to model a simple game to determine the best strategy for the Mexican Government and the cartels.
Applying Game Theory to a Model of the Mexican Drug War

To model this particular game, I will heed the advice of Ken Binmore, Director of Economic Learning and Social Evolution Centre at the University College of London. Binmore states that there are certain factors that must be satisfied before game theory might reasonably predict outcomes well. Those are “the game is simple, and presented to the subjects in a user-friendly manner”, "the subjects are paid adequately for performing well", and "sufficient time is available for trial-and-error learning". The game will be a simple matrix, the players are fighting to get a piece of this billion dollar industry, and this scenario has been going on since at least the 1980's, so all the players should have had enough time to perform trial and error of their respective strategies.

According to Dergal and his collaborators, the two most powerful cartels are the Gulf Cartel led by Chapo Guzman, and the Sinaloa Cartel led by Osiel Cardenas. While there are up to five more gangs in Mexico, the authors state that these two are the most prevalent, and these two will be used to keep our game simple. Our three players will be as follows: The Mexican Government, the Gulf Cartel, and the Sinaloa Cartel. We will now discuss their respective strategies.

Strategies for the players

The Mexican Government will have four strategies, and the cartels will then have retaliatory options.

Strategy 1: The Mexican Government fights one cartel

1. The cartel that is being attacked can seek help or both cartels fight individually

Strategy 2: The Mexican Government fights both cartels

2. The cartels can fight together against the government, or they can fight individually

Strategy 3: The Mexican Government legalizes drugs and consumption

3. The cartels can form a duopoly to control the market, or they can fight each other

Strategy 4: The Mexican Government can return to Pre-Status Quo (Heavy Corruption)

4. The cartels can form a duopoly to control the market, or they can fight each other
Decision Tree for the Mexican Government, Gulf Cartel, and Sinaloa Cartel
The Mexican Government will begin with Strategy 4 (Pre-Status Quo). Using Rios' cost benefit analysis, before the modern Mexican drug war began, the government was losing $3.5 Billion USD on average per year. For this reason, we establish that the Mexican government will lose 3.5 Billion USD per year if they decide to go with this strategy. If the Mexican government decides to pursue Strategy 1 (Only fight one cartel), then the government stands to lose $3.8 Billion USD. This stems from the losses the government will suffer from drug violence and corruption. To clarify, while the government attacks one cartel, the other cartel has an open option to attack the vulnerable government, increase its turf at the hands of the attacked cartel, and slowly monopolize the Mexican drug trade.

If the Mexican Government chooses Strategy 3 (Legalizing Drugs), then it stands to lose $4.43 Billion. Gil Kerlikowske, current director of the US Office of National Drug Control Policy, in Why Marijuana Legalization Would Compromise Public Health and Public Safety, clearly states that:

tax revenue collected from alcohol pales in comparison to the costs associated with it. Federal excise taxes collected on alcohol in 2007 totaled around $9 billion; states collected around $5.5 billion. Taken together, this is less than 10 percent of the over $185 billion in alcohol-related costs from health care, lost productivity, and criminal justice. Tobacco also does not carry its economic weight when we tax it; each year we spend more than $200 billion on its social costs and collect only about $25 billion in taxes.

Similarly, legalization would lead to lower prices and increase usage. Dr. Michael Grossman argues that a 10% reduction in price would cause the amount of cocaine users to increase between 4% to 10%. According to the United Nations Office on Drugs and Crime World Drug Report 2010, in the United States, 1 out of 3 people treated for drug abuse in 2008 dealt with cocaine problems. This treatment had a direct cost of $6 Billion USD and "almost half of all people entering drug treatment in the Americas do so due to cocaine (46%)". In Mexico, the cost attributed to treating cocaine addiction has been estimated at $1-2 Billion USD. Also, if the
cartels decide to continue fighting each other, further costs from violence and corruption will play a role.

Strategy 2 (Fighting both Cartels) has a payoff gain of $3.5 Billion USD. A modest estimation was used. Simply, Rios cost benefit analysis had a government loss of $3.5 Billion USD per year. Rios argues that "drug traffic brings negative consequences to the economy because of increased violence, corruption, and local drug abuse" and "taking these multiple factors together, the illegal drug industry has negative impact on the Mexican economy". Therefore, if the Mexican government can eliminate the cartels and eradicate the drug trade, it will at least gain the $3.5 Billion USD that it is currently losing per year.

**Strategies**

Due to Strategy 2 (Fighting both Cartels) having the highest payoff, at a gain of $3.5 Billion USD, this is the strategy that should be employed by the Mexican Government. With that in mind, the cartels have two options in response. They can choose to fight together and attempt to the defeat the government with the hope of forming some sort of duopoly, or they can fight individually and attack themselves and the government.

<table>
<thead>
<tr>
<th>Sinaloa Cartel</th>
<th>Gulf Cartel</th>
<th>Fight Together</th>
<th>Fight Individually</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fight Together</td>
<td>($6 Billion, $6 Billion)</td>
<td>($1.5 Billion, $10 Billion)</td>
<td></td>
</tr>
<tr>
<td>Fight Individually</td>
<td>($10 Billion, $1.5 Billion)</td>
<td>($3 Billion, $3 Billion)</td>
<td></td>
</tr>
</tbody>
</table>
The above matrix demonstrates the strategies and subsequent payoffs for both cartels. It becomes clear once again that both cartels should fight together to not only have an ally in fighting the government and other drug factions, but for the price increase that a duopoly would enable. The current drug market is around $6 Billion per year, and fighting together would allow the cartels to double their prices and profits. However, this payoff matrix is a classic Prisoner’s Dilemma. It can be seen that the best interest of the cartels is to cooperate, but there is a huge incentive to double cross once another. Let’s verify if Fight Together, Fight Together is a Nash Equilibrium.

1. Gulf Cartel (Fight Together) and Sinaloa Cartel (Fight Together) both get a payoff of $6 Billions USD

2. Can the Gulf Cartel switch strategies to obtain a higher payoff while the Sinaloa Cartel keeps the same strategy (Fight Together)?

3. Yes, if the Sinaloa Cartel continues to fight together, then the Gulf Cartel can choose to fight individually and increase its payoff to $10 Billion USD while the Sinaloa Cartel payoff drops to $1.5 Billion

4. Thus, the Gulf Cartel (Fight Together) and Sinaloa Cartel (Fight Together) is not a Nash Equilibrium.

Once again, the dominant strategy is for both cartels to betray each other and choose to fight individually. We can verify that this is a Nash Equilibrium.

1. Gulf Cartel (Fight Individually) and Sinaloa Cartel (Fight Individually) both get a payoff of $3 Billion USD

2. Can the Gulf Cartel switch strategies to obtain a higher payoff while
the Sinaloa Cartel keeps the same strategy (Fight Individually)?

2. No, if the Sinaloa Cartel continues to fight individually, then the Gulf Cartel can choose to fight together and decrease its payoff to $1.5 Billion USD while the Sinaloa Cartel payoff increases to $10 Billion

3. Thus, the Gulf Cartel (Fight Individually) and Sinaloa Cartel (Fight Individually) is a Nash Equilibrium.

Conclusions

In order to stop losing billions of dollars through drug violence, corruption, drug abuse, and lost opportunity cost, the Mexican Government must wage all out war on the cartels and eliminate them as soon as possible. This was the only strategy that resulted in any type of financial gain, and as such is chosen to be the optimal strategy for the Mexican Government to pursue. In response to this strategy, the cartels should choose to fight together in an attempt to take over the government and then establish a duopoly and/or a dictatorship. However, the problem faced by the cartels in working together is a classic example of the Prisoner's Dilemma. Thus, the dominant strategy is for the cartels to fight individually in hopes of seeking a higher payoff. Furthermore, a crucial aspect of game theory states that the players involved in the game must be rational. It can be argued that the cartels have been known to act irrationally with disregard to human life, but most importantly, with disregard to maximizing their own payoffs. Ideally, the cartels would work together in some way to establish stability in the way that P&G and Unilever have.
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