Corso di Laurea in MANAGEMENT AND BUSSINES FOR ECONOMICS

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"DYNAMIC GAME THEORY ANALYSIS OF THE RUSSO-UKRAINIAN CONFLICT: A HYPOTHETICAL MODEL"

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ABSTRACT

This thesis employs dynamic game theory to analyze the Russo-Ukrainian conflict within the framework of a hypothetical model. The Russo-Ukrainian conflict has been a matter of international concern, characterized by complex interactions, shifting strategies, and geopolitical implications. By utilizing dynamic game theory, this research aims to provide a comprehensive understanding of the strategic dynamics between the two nations and offers insights into potential resolutions and policy implications.

The study begins by establishing a theoretical foundation of the dynamic games, exploring the concepts of strategies and players' interactions in conflict scenarios. After that it presents a historical background of the conflict between the countries of our model, to then construct a hypothetical model that simulates the Russo-Ukrainian conflicts that allows the analysis of multiple decision points.

The finding of this research underscores the relevance of dynamic game theory in the modeling real-world conflicts.

TABLE OF CONTENTS

INTRODUCTION

In the complex landscape of international relations, conflicts between nations are not only recurrent but also multifaceted, with dynamics that challenge conventional modes of analysis and resolution. Among these conflicts, the Russo-Ukrainian dispute has emerged as a striking emblem of the intricate web of political, economic, and military considerations that define contemporary geopolitical strife. Rooted in historical legacies, cultural ties, and global citizens alike.

The Russo-Ukrainian conflict has defied easy categorization. It is not merely a clash of interests between two neighboring nations; rather; it encapsulates the broader complexities of modern international relations. The conflict's evolution has been marked by shifting alliances, information warfare, economic pressures, and military maneuvers, all set against the backdrop of a changing global order.

To comprehend and potentially resolve such a multifaceted conflict, we must turn to innovative analytical tools capable of capturing the dynamic and strategic nature of the interactions between the parties involved. This thesis undertakes this challenge by employing dynamic game theory, a framework that provides a powerful lens through which to study the strategic interactions of rational actors in evolving environments. By construing a hypothetical model that encapsulates the key elements of the Russo-Ukrainian conflict, we aim to unveil the hidden dynamics that shape decision-making processes and, ultimately, the course of the conflict itself.

Dynamic game theory allows us to simulate the strategic calculus of the involved parties at different stages of the conflict, accounting for their ability to adapt and revise their decision in response to changing circumstances.

This thesis is structured to provide a comprehensive exploration of dynamic game theory and its application to the Russo-Ukrainian conflict. It begins with a theoretical foundation, offering insights into the core concepts and principles that underlie dynamic games. Subsequently, it introduces a hypothetical model of the conflict's dynamics.

In this pursuit, we will explore the intricate strategies and decisions that shape the Russo-Ukrainian conflict within the dynamic game theory framework, where rationality meets uncertainty, and where the quest for stability and peace persists against the backdrop of geopolitical complexity.

1.DYNAMIC GAMES

1.1 Introducing dynamic games.

Dynamic games are mathematical models of the interaction between different agents who are controlling a dynamical system. Such situations occur in many instances like armed conflicts (e.g. wars), economic competition (e.g. investments in R&D for computer companies), parlor games (e.g. Chess). These examples concern dynamical systems since the actions of the agents or also called players, influence the evolution over time of the state of a system. The difficulty in deciding what should be the behavior of these agents stems from the fact that each action an agent takes at a given time will influence the reaction of the opponent(s) at later time. These notes are intended to present the basic concepts and models which have been proposed in the burgeoning literature on game theory for a representation of these dynamic interactions.

Dynamic games can be put into two categories, those with perfect information and those with imperfect information. In economics, **perfect information** is a feature of perfect competition. With perfect information in a market, all consumers and producers have complete and instantaneous knowledge of all market prices, their own utility, and own cost functions.

Games where some aspect of play is *hidden* from opponents – such as the cards in poker and bridge – are examples of games with **imperfect information.**

Our model it is going to be a case of imperfect information, thus one plays regardless of other's choice.

In a game we deal with the following concepts:

a.Players. They will compete in the game. Notice that a player may be an individual, a set of individuals.

*b.*A *move,* or a *decision* will be player's action. Also, borrowing a term from control theory, a move will be realization of a player's control or, simply, his control.

*c.*A player's*(pure) strategy* will be a rule (or function) that associates a player's move with the information available to him at the time when he decides which move to choose.

1.2 The importance of the Nash equilibrium in dynamic game theory.

Nash equilibrium is named after its inventor, John Nash, an American mathematician. It is considered one of the most important concepts of game theory, which attempts to determine mathematically and logically the actions that participants of a game should take to secure the best outcomes for themselves.

The reason why Nash equilibrium is considered such an important concept of game theory relates to its applicability. The Nash equilibrium can be incorporated into a wide range of disciplines, from economics to social sciences.

To quickly find the Nash equilibrium or see if it even exists, reveal each player's strategy to the other players. If no one changes their strategy, then the Nash equilibrium is proven.

Nash equilibrium is often compared alongside dominant strategy, both being strategies of game theory. The Nash equilibrium states that the optimal strategy for an actor is to stay the course of their initial strategy while knowing the opponent's strategy and that all players maintain the same strategy. Dominant strategy asserts that the chosen strategy of an actor will lead to better results out of all the possible strategies that can be used, regardless of the strategy that the opponent uses.

Both terms are similar but slightly different. Nash equilibrium states that nothing is gained if any of the players change their strategy while all the other players maintain their strategy. Dominant strategy asserts that a player will choose a strategy that will lead to the best outcome regardless of the strategies that the other players have chosen. Dominant strategy can be included in Nash equilibrium, whereas a Nash equilibrium may not be the best strategy in a game. In game theory is a situation in which a player will continue with their chosen strategy, having no incentive to deviate from it, after taking into consideration the opponent's strategy.

To find solution in a game, one would have to model out each of the possible scenarios to determine the results and then choose what the optimal strategy would be. In a two-person game, this would take into consideration the possible strategies that both players could choose. If neither player changes their strategy knowing all the information, a Nash equilibrium has occurred.

In most cases, such as in war (which is on what our model will be structured on)—whether that be a military war or a bidding war—an individual rarely knows the opponent's strategy or what they want the outcome to be. Unlike dominant strategy, the Nash equilibrium doesn't always lead to the most optimal outcome. It just means that an individual chooses the best strategy based on the information they have.

Furthermore, in multiple games played with the same opponents, the Nash equilibrium does not take into consideration past behavior, which often predicts future behavior.

2. GAME THEORY APPLIED IN TERMS OF CONFLICTS

2.1 What is a conflict?

Is a situation, in which the interests of the parties collide, and a conflict of interests occurs. Each of the participants wants something, not what other want.

Now, we can dig more in depth of Game theory in terms of conflicts. It is tightly connected with the social sciences. Modern socio-economic studies are based on game theory. The application of game theory can be understood in two ways. It can be like an understanding of the surrounding situation, political, economic or transport situation. It can also be of direct benefit to the person who uses it. The simplest examples of conflict are games (checkers, chess, card games, etc.). They differ in that they are conducted according to certain rules. The rules of the game are a system of conditions that indicate what opportunities are given to players (a list of possible moves); what result (gain, loss) each given set of moves leads to. But in real-life rules are not always defined. Not every conflict that occurs in practice proceeds according to the rules. To make a mathematical analysis possible of a conflict, one need to present the conflict in a game form, that is, indicate the strategies (actions) that are possible for the participants, and specify what the result will be if the players choose a certain strategy.

Thus, the game is a conflict with clearly defined conditions.

Game theory gives an opportunity to predict the consequences of our actions and the actions of other people. It often happens that the result of a conflict – even with quite certain strategies of the participants – is impossible to predict exactly, since it depends on the case. Such random circumstances interfering during the game can be, for example, shuffling and dealt cards, hitting or not hitting the target when shooting, etc. Then, instead of “game result”, you need to talk about the average result, i.e., average per game if a sufficiently large number of games is played.

2.2 Russo-Ukrainian conflict

Since the players of our models are Russia and Ukraine, we shall have a look at how this conflict started for a clearer background.

The conflicts between Russia and Ukraine have been ongoing since 2014 and have had far-reaching political, territorial, and humanitarian consequences. The origins of the conflicts can be traced back to Ukraine’s decision to pursue closer ties with the European Union, which sparked protests in Ukraine known as the Euromaiden movement. The movement led to the ousting of Ukraine’s pro-Russian President Viktor Yanukovych in February 2014.

Following Yanukovych's removal, Russia annexed Crimea, a region of Ukraine with a significant Russian-speaking population. This move was widely condemned by the international community, which considered it a violation of Ukraine and marked the beginning of the armed conflict in eastern Ukraine.

In eastern Ukraine, predominantly Russian-speaking regions, including Donetsk and Luhansk, separatist movements emerged, supported by Russia. These separatists declared independent republics and sought to break away from Ukraine. The Ukrainian government viewed these actions as illegal and launched military operations to reign control of the territories.

The conflict in eastern Ukraine escalated into a full-scale war characterized by clashes between Ukrainian armed forces and separatist groups, often with support from Russian troops and equipment. The war has resulted in a significant number of casualties and humanitarian crisis, with thousands of people displaced from their homes and infrastructure heavily damaged.

Efforts to resolve the conflict have been made through diplomatic negotiations, most notably the Minsk agreement in 2014 and 2015.However, the implementation of these agreements has been challenging, with frequent violations of the ceasefire has been challenging, with frequent violations of the ceasefire and limited progress towards a peaceful resolution.

The conflict between Russia and Ukraine has also had broader geopolitical implications. It strained Russia's relations with the West, leading to economic sanctions imposed by Western countries on Russia. NATO has increased its presence in Eastern Europe in response to the perceived threat from Russia, and the conflict has further fueled tensions between Russia and other Western powers.

Despite international efforts to find a peaceful solution, the conflict between Russia and Ukraine remains unresolved. The situation continues to evolve, with ongoing negotiations, sporadic fighting, and a fragile ceasefire. The conflict has had a lasting impact on the region and has significantly affected the lives of people in both Ukraine and Russia.

3. INTRODUCING THE MODEL

Now that we have the information that we need about the dynamic game theory and the background of the two countries, we can move forward into constructing our hypothetical model representing the on-going conflict.

Introducing the dynamic game model:

Players:

1.Russia

2.Ukraine

Actions:

1. **Russia (R)**

   -Deploy troops (D)

   -Launch airstrikes(A)

   -Initiate cyberattacks(C)

   -Negotiate for peace (N)

2. **Ukraine (U)**

   -Mobilize forces(M)

   -Seek international support (S)

   -Conduct defensive operations (O)

   -Negotiate for peace(N)

The payoffs are represented as a utility value for each player. Higher values indicate more favorable outcomes for the respective player, while lower values indicate less favorable outcomes.

Game dynamics:

- Both Russia and Ukraine make simultaneous decisions regarding their actions.

-The actions taken by both players influence the outcomes and subsequent decisions.

- The game is played in a repeated manner, allowing players to reassess their strategies based on the evolving situation.

So it is a case of imperfect game.

Actions UKRAINE / RUSSIA	M (mobilize forces)	S (seek support)	O (conduct operations)	N (negotiate for peace)
D (deploy troops)	(2;1)	(1;4)	(0;1)	(0;1)
A (launch airstrikes)	(3,2)	(1;2)	(0;1)	(0;1)
C (initiate cyberattacks)	(4,1)	(3;3)	(1;0)	(0;1)
N (negotiate for peace)	(1;0)	(1;0)	(1;0)	(3;2)

Fig 3.1

<u>For Russia:</u>
Maximum payoff for Russia in Row D:2
Maximum payoff for Russia in Row A:3
Maximum payoff for Russia in Row C:4
Maximum payoff for Russia in Row N:3
The maximum payoff for Russia is *(4;2)*
<u>For Ukraine:</u>
Maximum payoff for Ukraine in Column M:2
Maximum payoff for Ukraine in Column S:4
Maximum payoff for Ukraine in Column O:1
Maximum payoff for Ukraine in Column N:2
The maximum payoff for Ukraine is *(1;4)*

3.1. A better understanding at the payoffs

Deploy troops. From the information provided on an analysis of the Russo-Ukrainian war on 2023, there was an estimated total military personnel of 1.330.900 for Russia, while for Ukraine the number was 500.000. Giving so higher payoff for Russia's strategy if Ukraine chooses to mobilize forces. The tables turn if Ukraine chooses to Seek international support as for its relations with the NATO. The security of Ukraine is of great importance to NATO and its member states. The Alliance fully supports Ukraine's inherent right to self-defense, and its right to choose its own security arrangements, giving so estimated military personnel of 5.817.100. In this case the payoff it is higher for Ukraine. Moving on to the third strategy for Ukraine, conduct operations, it will give a higher payoff for Ukraine because conducting operations it means that it will seek the best strategies in its favor, excluding here, when Russia Initiates cyberattacks, and negotiates for peace that I will explain later on. In case Ukraine negotiates for peace, the payoff will be slightly higher for Ukraine since history has taught us that the party offered the negotiation will have to give up something.

Launching airstrikes. The analysis done in 2023 arrived at the conclusion that Russia has a great advantage, if Ukraine chooses to mobilize forces, by a total number of aircrafts being 4.182, while Ukraine's number is 312. Even in this case if Ukraine seeks international support, NATO will contribute with a total number of 20.633 in air force, giving so a higher payoff to Ukraine. The same analysis done above can be put here if Ukraine conducts operations or negotiates for peace.

Initiate cyberattack. Looking at the case when Ukraine plays to mobilize forces. For the cyber power Harvard's Belfer Center for Science and International Affairs released 2022 National Cyber Power Index (NCPI), a follow-up to its groundbreaking 2020 index that ranks 30 countries according to their capability and intent to pursue eight objectives of cyber power. In which Russia moved ahead of the United Kingdom into third place (China remains second), "largely as a result of greater demonstrations of intent and capability in the fields of espionage, destructive attacks, and domestic surveillance," according to the announcement of the NCPI's release and Ukraine missed the Top 10, coming in 12th, but making a giant leap from 29th in 2020. So, the payoff it is going to be higher for Russia, but if Ukraine chooses to seek international support, it will have a contribution such as that of the United States that stays first place on the Cyber power rankings. The payoffs in this case will be a tie for both countries. In case Ukraine conducts operations, it will still give advantage to Russia since the power Russia has in the cyberattacks it is much higher. For strategy 'Negotiate for peace' follows the same logic as above.

Negotiating for peace. The party seeking peace negotiations generally has a higher payoff, as it may compel the other party to make concessions. For the payoffs (3;2), It is slightly higher for Russia as it is the initiating party in real life.

4.SOLVING THE GAME

Representing a conflict, such as war, finding pure Nash equilibria involves identifying the situations where neither player has an incentive to unilaterally deviate from their chosen strategies given the strategies of the other player. In a war scenario, players are making decisions to maximize their own payoffs, which might represent factors like military strength, resources, or geopolitical objectives. To solve the matrix of the imperfect game I am going to use the Dominance Strategy Rule, that suggests that a strategy can be eliminated from consideration if it is always dominated by another strategy, meaning that it always yields a worse outcome regardless of the other player's strategy.

-Analyzing row "D"

Starting with strategy (D, M): Russia's payoff is 2, and Ukraine's payoff is 1. Ukraine can unilaterally improve their payoff by changing their strategy to S, resulting in a payoff of 4, so (D, M) is not a Nash Equilibrium.

Strategy profile (D, S): Russia's payoff is 1, and Ukraine's payoff is 4. Russia can improve its payoff by changing to row A, resulting in a higher payoff of 3. Therefore, (D, S) is not a Nash Equilibrium.

Strategy profile (D, O): Russia's payoff is 0, and Ukraine's payoff is 1. Both players can unilaterally improve their payoff . Russia by changing its strategy to row C, resulting in a payoff of 1 and Ukraine can change it to column S. Therefore, (D, O) is not a Nash equilibrium.

Strategy profile (D, N): Russia's payoff is 0, and Ukraine's payoff is 1. Both players can unilaterally improve their payoff by changing their strategy. Russia can change to row N, resulting in a payoff of 3, and Ukraine can change to column S, resulting in a payoff of 4. Therefore, (D, N) is not a Nash equilibrium.

-Analyzing row "A"

Strategy profile (A, M): Russia's payoff is 3, and Ukraine's payoff is 2. Russia can unilaterally improve their payoff by changing their strategy to row C, resulting in a payoff of 4, so (A, M) is not a Nash equilibrium.

Strategy profile (A, S): Russia's payoff is 1, and Ukraine's payoff is 2. Russia can unilaterally improve its payoff by changing their strategy changing it to row C, resulting in a payoff of 3. Therefore, (A, S) is not a Nash equilibrium.

Strategy profile (A, O): Russia's payoff is 0, and Ukraine's payoff is 1. Both players can unilaterally improve their payoff by changing their strategy. Russia can change to row C, resulting in a payoff of 1, and Ukraine can change to column S, resulting in a payoff of 2. Therefore, (A, O) is not a Nash equilibrium.

Strategy profile (A, N): Russia's payoff is 0, and Ukraine's payoff is 1. Both players can unilaterally improve their payoff by changing their strategy. Russia can change to row N, resulting in a payoff of 3, and Ukraine can change to column S, resulting in a payoff of 2. Therefore, (A, N) is not a Nash equilibrium.

-Analyzing row "C"

Strategy profile (C, M): Russia's payoff is 4, and Ukraine's payoff is 1. Ukraine can unilaterally improve their payoff by changing their strategy to column S.

Strategy profile (C, S): Russia's payoff is 3, and Ukraine's payoff is 3. No player can unilaterally improve their payoff by changing their strategy, so (C, S) is a Nash equilibrium.

Strategy profile (C, O): Russia's payoff is 1, and Ukraine's payoff is 0. Ukraine can unilaterally improve their payoff by changing their strategy, to column S, resulting in a higher payoff of 3, so (C, O) is not a Nash equilibrium.

Strategy profile (C, N): Russia's payoff is 0, and Ukraine's payoff is 1. Both players can unilaterally improve their payoff by changing their strategy. Russia can change to row N, resulting in a payoff of 3, and Ukraine can change to column S, resulting in a payoff of 3. Therefore, (C, N) is not a Nash equilibrium.

-Analysing row "N"

Strategy profile (N, M): Russia's payoff is 1, and Ukraine's payoff is 0. Both players can unilaterally improve their payoff by changing their strategy. Russia can change to row C, resulting in a payoff of 4, and Ukraine can change to column N, resulting in a payoff of 2. Therefore, (N, M) is not a Nash equilibrium.

Strategy profile (N, S): Russia's payoff is 1, and Ukraine's payoff is 0. Russia can unilaterally improve its payoff by changing to row C, resulting in a payoff of 3 and Ukraine can change it to column N, resulting in a payoff of 2. Therefore, (N, S) is not a Nash equilibrium.

Strategy profile (N, O): Russia's payoff is 1, and Ukraine's payoff is 0. Ukraine can unilaterally improve its payoff vu changing to column N, resulting in a payoff of 2. Therefore, (N, O) is not a Nash equilibrium.

Strategy profile (N, N): Russia's payoff is 3, and Ukraine's payoff is 2. No player can change their strategy payoff so (N, N) is a Nash equilibrium.

After analyzing all possible strategy profiles, we find that the Nash equilibria in this game are:

1.(C, S) - Initiate cyberattacks, Seek international support with a payoff of (3,3)

2.(N, N) – Negotiate for peace, Negotiate for peace with a payoff of (3,2)

These are the strategy profiles where neither player has an incentive to unilaterally deviate from their chosen strategy.

The game here has two Nash equilibria, it is typically referred to as a game with multiple or multiple pure strategy Nash equilibria. The existence of multiple equilibria means that there are different sets of strategies for the players where no player has an incentive to unilaterally deviate from their chosen strategy.

As seen, the players have multiple stable points of equilibrium where their strategies are mutually consistent. Each equilibrium represents a combination of strategies where no player can improve their payoff by changing their strategy while the other players keep theirs unchanged.

This analysis was made using the Dominance rule to reduce the size of the payoff matrix.

The principle of dominance states that if one strategy of a player dominates over the other strategy in all conditions then the later strategy can be ignored. A strategy dominates over the other only if it is preferable over other in all conditions.

Rules: 1. If all the elements of a column (say i-th column) are greater than or equal to the corresponding elements of any other column (say j-th column), then the i-th column is dominated by the j-th column and can be deleted from the matrix.

2. If all the elements of a row (say i-th row) are less than or equal to the corresponding elements of any other row (say j-th row), then the i-th row is dominated by the j-th row and can be deleted from the matrix.

To have a clearer visualization we shall demonstrate it:

Giving the game matrix:

	M	S	O	N
~~D~~	~~(2,1)~~	~~(1,4)~~	~~(0,1)~~	~~(0,1)~~
~~A~~	~~(3,2)~~	~~(1,2)~~	~~(0,1)~~	~~(0,1)~~
C	(4,1)	(3,3)	(1,0)	~~(0,1)~~
N	(1,0)	~~(1,0)~~	(1,0)	(3,2)

- Column O ≤ Column S, so we remove column O
- Row C ≥ Row A , so remove Row A
- Column S ≥ Column N, so remove Column N
- Column S ≥ Column M, so remove Column M
- Dominant ones are (3,3) and (3,2), so we remove the rest.

As we can see, the results of the Nash equilibrium are the same as above. The reduction of the non-dominant strategies has brought us to the dominant payoffs, respectively being (C, S) and (N, N), so Ukraine it is going to Seek international support while Russia Initiates cyberattack and on the other case it will both negotiate for peace.

5.CONCLUSION

The application of game theory to the analysis of the war scenario between Russia and Ukraine has provided valuable insights into the strategic decision-making processes that underlie conflicts. By representing the conflicts as a simplified game matrix, we have explored various strategic choices and their implications. Through the identification of Nash equilibria, we have shed light on stable points where neither player has an incentive to unilaterally deviate from their chosen strategy.

The hypothetical outcomes crafted based on these equilibria showcased potential narratives for resolving the conflict. These outcomes demonstrated the importance of negotiation strategies that blend military considerations with diplomatic initiatives. The equilibrium points served as reference benchmarks for these negotiations, guiding both countries toward cooperative resolutions.

It is important to note that this analysis provides a theoretical framework that simplifies the complexities of real-world geopolitical conflicts. The outcomes are contingent on the assumptions made regarding payoffs, interpretations, and strategies. Additionally, the dynamics of international relations encompass a myriad of factors that extend beyond the boundaries of this analysis.

In a world where geopolitical tensions can escalate rapidly, game theory offers a valuable tool for understanding strategic interactions and potential outcomes. By recognizing the interplay between military strength, resources, and diplomatic engagement, stakeholders can better navigate the intricacies of conflicts and work towards resolutions that prioritize stability and cooperation.

Ultimately, the game theory analysis presented here serves as a starting point for broader discussions on conflict resolution, strategic decision-making, and the intricate balance between military actions and diplomatic solutions in complex international scenarios.

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